

Assessing the Extent that the Gender and STEM Practice - Oriented Literature is Evidence-Based

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Abstract

One principal way to judge if the activity or program described in a practice-oriented publication is worth replicating is to consider the strength of its foundational component. A strong foundational component supports the credibility of an initiative by demonstrating that it was designed with an understanding of other similar initiatives and with evidence that there was a reasonable promise that the desired outcomes were realistically achievable. This paper reports on the findings of a mixed methods content analysis of 142 practice-oriented articles published in three different refereed venues between 1995 and 2009. A scale to measure the quality of the foundational component of the practice-oriented publications was used in the quantitative phases to test if there had been a change in the relative number and quality of practice-oriented publications over time. The validity of the scale was tested in subsequent qualitative phases of the project by an inductive examination of the characteristics of top-scoring articles. Results of the quantitative analysis indicated that the average quality rating of the foundational element of the articles was relatively low (3.37 out of a possible 6 points). The scale proved effective in distinguishing articles that were exemplary in other ways as well. The low overall quality score on the foundational component of practice-oriented publications either means that the authors of these publications are failing to provide ample documentation that these initiatives were evidence-based or the content analysis reveals a long-standing trend toward the adoption of non-evidence based practices.

Keywords: Gender and STEM, Practice-oriented literature, Evidence-based practice

1. Introduction

Evidence-based practice (EBP) is an interdisciplinary approach with a long history in the health disciplines. It is an approach that argues policy and practice should be justified in terms of sound evidence about their likely effects. Currently, the term evidence-based practice is used with two different meanings. One meaning is associated with “best-practice.” The other meaning is associated with evidence as the basis for practice (Slavin, R. E., 2002) and practitioner decision-making. (Mullen, E.J., 2002) Although the discourse has been heavily shaped by its application to clinical settings, the parlance of evidence-based practice now extends to other fields and beyond the limitation of a single experimental research design. (Slavin, R. E., 2002)

The social sciences are increasingly referring to evidence-based programs. The Society of Prevention Science created a set of standards of evidence that have been used by government agencies to establish lists of model programs. In general, evidence-based programs are based on a clearly articulated and empirically supported theory and have a detailed description of the intervention and measurement design with what outcomes were produced in what populations with what intervention. They have measureable outcomes that have been assessed with psychometrically strong measures, including long-term follow-ups and have been tested in a scientifically sound way with comparison conditions, optimally through randomized controlled studies.

The practice-oriented literature is important in the arena of activities designed to promote interest in science, technology, engineering, and math (STEM) because it promotes continued innovation by making public information

about the design and implementation of activities and courses that strive to enhance learning and promote interest in careers in science and engineering. Practice-oriented publications are those that have among their principal purpose the intent to describe the design, delivery, and outcomes of educational activities, classes, or programs in K-12 or at the collegiate level.

The purpose of the sequential mixed methods content analysis described in this paper is to provide results of a synthesis of the practice-oriented published STEM literature in three sources: the proceedings of the Frontiers in Engineering Education (FIE) and Association of Engineering Education (ASEE); and the *Journal of Women, Minorities, in Science and Engineering*(JWMSE). There were several reasons for selecting these sources. All are refereed and reach national and internal audiences of STEM educators. Practice-oriented articles in engineering education frequently cite references from these sources.

This descriptive study examines trends over time in the relative number of practice-oriented publications in the three venues and considers whether a scale developed for purposes of the study points to an improvement in the quality of this literature over time. An improvement in the quality score over time would suggest that new practices are increasingly evidence based. It also suggests maturation in this distinct field of inquiry and that newer publications were more firmly grounded than older publication in the growing literature base.

The rationale for using mixed methods was in part to test the validity of a scale developed for purposes of the project to identify exemplary practice-oriented publications that novice authors might use as models. We consider an inductive approach to analysis as a fundamentally qualitative approach; the deductive approach to analysis as a fundamentally quantitative approach. The purposes of this mixed method project fit a development design (Greene, Caracelli, & Graham, 1989) in that the results from the first quantitative phases of the project became the basis for further, extended investigation in the subsequent qualitative phases of the project that sought to demonstrate the validity of the scale designed to identify exemplary practice-oriented publications.

The research questions for the mixed methods study reported in this paper are:

- 1) (QUANT) Has there been a change over time (1995-2009) in the relative number of practice-oriented publications appearing in the three sources?
- 2) (QUANT) What is the average foundational quality of practice-oriented publications? Has the foundational quality score improved over time (1995-2009)?
- 3) (QUAL) What are additional characteristics of publications scoring the highest on the evidence-based scale?
- 4) (QUANT) What evidence is there to support the validity of the scale developed to evaluate the foundational quality of practice-oriented publications?

The analysis reported in this paper was conducted as part of a supplemental grant to a larger funded project (NSF GSE 08322913) funded by the Program for Gender Equity (PGE) at the National Science Foundation. The supplemental grant was designed with the goal of promoting cross-disciplinary collaboration by developing an accessible and comprehensive indexed database of refereed gender and STEM publications. This database makes it possible to conduct synthetic and longitudinal studies of research publications in gender and STEM. It also makes it possible to evaluate multiple dimensions of the quality of these publications in this cross disciplinary topical area in order to assess if the field is moving forward in that newer initiatives are grounded in a solid foundation that reflects knowledge of previously produced literature in the field.

2. Literature Review

The foregrounding of language about evidence-based practice by funders like the National Science Foundation reflects not only the influence of the political climate that arose around the No Child Left Behind Act of 2001, but also calls for accountability and assurances that proposals they funded to enhance practice were grounded in convincing evidence of their potential to have the promised effect on targeted outcomes. These affected not only the way the proposals were evaluated but also a shift to expecting a strong research and evaluation component in proposals for funding, even for those designed primarily to enhance practice.

Following the enactment of the No Child Left Behind Act, the leading and largest educational professional research association convened a panel of experts in a variety of methodologies to develop the American Educational Research Association (AERA) Standards for Reporting on Empirical Social Science Research (2006). These standards apply to all types of social science research and research reports, including those with a practical intent. The two overarching principles established in the preamble to the Standards are, first, that there is adequate evidence or warrants to justify

the results and conclusions and, secondly, that research reports are written in such a way that they are transparent or explicit in the details provided about the logic of inquiry from the design through the execution of the study.

The first part of the AERA Standards deal with what could be called the foundational element of a study or what the AERA Standards refer to as problem formulation. “The importance of this step in evaluating a single study deserves additional attention” (Leech, Dellinger, Brannagan, & Tanaka, 2010, p. 29). According to the Standards, “The problem formulation answers the question of why the results of the investigation would be of interest to the research community and how an investigation is linked to prior knowledge and research” (2006, p. 34). The foundational element reflects “researchers’ prior understanding of a construct and/or phenomenon under study” (Dellinger & Leech, 2007, p. 323). If the study concerns practice, then the Standards specify that it should be made clear “what those concerns are, why they are important, and how this investigation can address those concerns” (p. 34). The Standards go on to state that it should be clear why the intervention is appropriate for the group studied, with appropriate citations.

Several reasons can be put forward for why the foundational element is a necessary condition of overall quality of a scholarly publication. Situating the research in the appropriate body of literature provides initial evidence of construct validity (Dellinger & Leech, 2007; Leech et al., 2010), establishes the credentials of the authors to conduct the research, and is necessary to establish the credibility of the conclusions (Beach, 2006). The foundational element foreshadows the conclusions by providing information about how to interpret the findings, their consequences, and their transferability to other settings (Leech et al., 2010). Without a strong foundational element, it is impossible for authors to situate their in ways that make its contribution to knowledge evident. This is a point Beech made when he said:

It is impossible to construct conclusions without relying on prior knowledge. At the same time, if the meaning of research findings is dictated solely by prior knowledge, then we cannot learn from new studies. The problems that researchers face, therefore, is not one of how to put aside prior knowledge, but rather one of how to capitalize on prior knowledge and use it to extract as much *new knowledge* (italics his) as possible from the findings ” (Beach, 2006, p. 502).

A strong foundation makes it possible to pinpoint exactly the contribution of the results and conclusions to the body of knowledge.

While it can be said that a strong foundational element is a requirement for an article to merit the designation of being exemplary, it is not the only indicator of quality that is critical to an overall assessment of quality. Other elements, such as the execution of the research and the quality of inferences are part of a comprehensive framework to evaluate the overall quality of research reports (Dellinger & Leech, 2007; Leech et al., 2010; O’Cathian, 2010). A report about practice does not merit replication, and thus be worthy of vetting to a larger audience, without a strong foundational element that signals that the initiative was evidence based.

3. Methods

Following the creation of the database of gender and STEM publications (N=612), this mixed methods content analysis was conducted in six steps.

- 1) A database of gender and STEM articles was coded in NVIVO10 using an initial, deductively derived 10-item coding scheme. One of the codes distinguished practice-oriented articles from research and conceptual articles.
- 2) A pilot study was conducted with 25 practice-oriented publications to gauge the effectiveness of a scale that was developed for purposes of the study to measure the foundational quality of the publications.
- 3) The remaining practice-oriented publications were evaluated using the foundational scale.
- 4) During the pilot study, one top-scoring article was coded using an emergent approach and three additional characteristics of quality were identified.
- 5) All the top-scoring articles were coded to determine if the additional quality characteristics were present.

More details about the different phases of the research project are described in the next section.

3.1 Creation of the Database of Practice-Oriented Publications

A database of all gender related publications appearing in three sources (FIE and ASEE proceedings, JWMSE) was created and coded in NVIVO10 software. The database was assembled by conducting electronic searches of the literature in four sources to identify publications that used the search terms [gender or female or girls or women or

gender] and [science or engineering or technology] in the title. All publications from the JWMSE and those meeting the search terms from 1995-2009 were added to the database (N=612).

All of the articles were initially coded for ten different variables. These variables were: three keywords; if it acknowledged support from funding; if the sample included members of other under-represented groups and, if so, what groups, in addition to women; the nature of the sample (e.g. K-12 students, K-12 teachers or other personnel, undergraduate students, community college students, etc.); discipline or field of focus; if it was single or multi-institutional; publication year and source; type of publication (research, practice, literature review, theoretical or conceptual).

The focus of this paper is on the sub-set of articles identified to be practice-oriented (N=142). Practice-oriented publications were identified as those that had among their principal purpose the intent of describing the design, delivery, and outcomes of educational activities, classes, or programs in K-12 or at the collegiate level. Research-based and practice-oriented publications were distinguished in terms of the stated purpose of the publication. These two types of publications also tended to differ in the presentation and analysis of data. Most practice-oriented articles contained little or no data.

3.2 Pilot Study

An initial pilot study was conducted with a random sample of practice-oriented publications (n=25) from all three sources in order to develop a set of operational decision rules about how to apply a 6-point ordinal scale developed by the lead author to assess the extent that the documentation presented in each article reflected a grounding in evidence. Raters focused on explicit language provided in the text. Raters applied a value of "0" to articles with no supporting related references; "1" to those with one related reference; "2" to those with two related references, and "3" to those with three or more related references. Articles scored with a "4" were those with three or more relevant references and the references to the literature included implicit or explicit references that indicated that data to support the effectiveness of the intervention was considered before the decision was made to initiate the intervention. A "5" on the evidence-based scale indicated three solid references plus the presence of explicit language that the intervention was a scale-up of a smaller project or pilot study. The highest score, "6", was applied by the scorers when evidence was supplied in the publication that the practice derived from a theoretical model or framework. Raters exercised some judgment in determining which references to include in the count. Google and Wikipedia references, for example, were not included.

During the pilot study, three readers used the 6-point foundational scale to score 25 articles. They continued meeting and comparing scores until three-way inter-rater reliability was consistently in excess of 90%. The satisfactory level of inter-rater reliability was taken as one indication that a set of operational rules for coding was being used systematically. Preliminary frequency counts supported continued use of a 6-point scale. The second and third author went on to score all the remaining practice-oriented publications.

3.3 Inductive Analysis of High Scoring Articles

A qualitative or inductive approach was used by the second and third of the authors in the third phase and final phase of the study. They used an open or inductive approach to identify additional characteristics of the single article that was scored a value of 6 on the 6-point scale. This was the only practice-oriented publication that met all of the criteria identified in the scale.

4. Results

The results reported in this paper are from an analysis of the body of literature of practice-oriented publications appearing in three sources often accessed by engineering educators (ASEE, FIE, and JWMSE). This type of publication accounted for 142 of 612 (23.2%) of the gender-related publications appearing in the three sources between 1995 and 2009. Most of these articles described either formal or informal activities or courses designed to promote the recruitment or retention of students in STEM at the K-12 or undergraduate level. Very few articles described a program or activity involving graduate students or faculty members.

In the following section, we describe trends over time and by source in the relative number of practice-oriented publications. In addition, we report on what the evidence-based foundational scale tells us about the quality of these publications and the extent they were grounded in a body of evidence. Finally, we report on the findings from the qualitative analysis of additional qualities of exemplary publications.

4.1 Research Question 1: Number of Practice-Oriented Publications by Time Frame and Source

The first table displays the total number of gender-related practice-oriented publications appearing in the three sources for each of three time periods between 1995 and 2009. The numbers in some of the cells are too small to warrant the use of statistical analysis. More than 20% (142 of 612) of all the publications appearing in these three sources between 1995 and 2009 were practice-oriented. Overall, practice-oriented publications were the highest percent of all publications appearing in the ASEE proceedings (n=90, 32.6%), followed by the proceedings from the FIE conferences (n=18, 30%). Practice-oriented publications were the smallest percentage of all articles appearing in JWMSE (n=34, 12.2%).

Table 1. Number of practice-oriented articles by time frame and source

Time Frame	ASEE		
	Practice	Total	Percent
1995-1999	11	27	40.74
2000-2004	40	100	40.00
2005-2009	39	149	26.17
Total	90	276	32.61
Time Frame	FIE		
	Practice	Total	Percent
1995-1999	0	0	0.00
2000-2004	14	26	53.85
2005-2009	4	34	11.77
Total	18	60	30.00
Time Frame	JWMSE		
	Practice	Total	Percent
1995-1999	5	88	5.68
2000-2004	15	86	17.44
2005-2009	14	102	13.73
Total	34	276	12.32

We hypothesized that there would be a decline in the number of practice-oriented publications in the various venues over time as the disciplines matured and the research base became more robust. This hypothesis was supported in that percentage of all publications that were practice-oriented declined in each of the three venues for the last time period (2005-2009). The percentage dropped from 40% to 26.17% for ASEE publications during that time period and from 53.8% to 11.7% for FIE. The decline was not so dramatic for publications appearing in JWMSE.

4.2 Research Question 2: The Quality of the Foundational Element of the Practice-Oriented Literature

Table 2 provides the results of the measure of foundational quality used for this paper by showing the number of practice-oriented articles that were scored at each point on the 6-point ordinal scale. The higher the score on the scale, the stronger the foundational materials in that they provided more evidence from the literature to justify the choice of intervention or activity described in their publication. Low scores signal that authors failed to provide documentation that their decision to initiate a new activity, course, or program grew out of knowledge of other initiatives with similar goals that had been proven successful.

Table 2. Frequency of the quality scale of the foundational element of practice oriented publications

Score	Practice Articles	
	Frequency	Percentage
0	10	7.04
1	5	3.52
2	8	5.63
3	44	30.99
4	50	35.21
5	24	16.90
6	1	0.70
Total	142	100.00

Overall, the scores on the evidence-based scale indicate that the quality of the practice-oriented literature is not high.

Results of a one-way analysis of variance (ANOVA) considering differences in quality scores across time frame, disputed the hypotheses that the quality of practice-oriented publications has improved over time ($F=1.490$; $p=.229$).

The overall mean on the scale designed to measure the foundational grounding of the article was 3.37 out of a possible 6 points. This indicates that most publications provided three or fewer references to justify the selection of an activity or program. About one-tenth of the articles either made no reference to literature supporting the choice of the activity, or provided only one reference.

On the other hand, 25 twenty-five of 142 publications (17.6%) scored either a 5 or 6 on the scale. The authors of these publications provided stronger documentation for the activity they chose by including explicit references to a pilot or scale up study or by describing the grounding of the activity in a theoretical or conceptual model or framework. Other characteristics of these articles that might warrant the designation of exemplary are discussed in the next section.

4.3 Research Question 3: Additional Characteristics of Exemplary Evidence-Based Practice-Oriented Publications

Our third research question required the use of a qualitative or inductive approach to identify additional characteristics of the design and execution of practice-oriented publications that scored high on our foundational quality scale. Only one article surfaced during the pilot study where three raters independently nominated as exemplary in an overall sense. This was the only article of 124 to be scored by all raters as a 6 on 6-point scale. This was an article by Jessup, Sumner, and Barker appearing in JWMSE in 2005 and titled, *Report form the Trenches: Implementing Curriculum to Promote the Participation of Women in Computer Science*. The article describes the design and implementation of an undergraduate computer science course at the University of Colorado at Boulder in which students work with local community service agencies to build computational solutions for problems the agencies confront.

The first quality beyond the foundational component that distinguished the Jessup et al. (2005) publication is that the authors built credibility early in the publication in the review of the literature. Specifically, the authors cited recommendations from other successful programs and then explained how they would implement these recommendations. By establishing this strong credibility early in the review, the authors generated interest in the program's methods, and, more importantly, they developed a stronger case for the program's purpose. The authors explained:

Several types of solutions are proposed in the literature to attract and retain women in computing study ... we have borrowed from some of the recommendations above, as well as from the more general literature on women's preferences, in building our course (p. 275).

The second exemplary feature of *Report from the Trenches* (Jessup, E., Sumner T., Barker, L., 2005) is Jessup et al. (2005) explicitly identified and described the theory TC was grounded in. The authors provided an explanation that facilitated understanding of the paradigm and proceeded with a strong rationale for the application of the theory. Moreover, Jessup et al. (2005) subsequently provided documentation of how the theory was integrated into the course they designed. By describing how designed-based learning might be observed, the authors created an opportunity for the reader to understand the theory in context of the program:

Thus, in design-based learning, skill and knowledge development activities are all situated within an authentic problem-solving context in which success is measured by the ability to produce a useful and useable artifact... Design-based learning can counteract impersonalization and humanize both the classroom setting and the technology-development process. Within the TC course, the projects are more complex than any student can take on individually. By necessity, all work must be performed by teams of students working together intensely, both within and outside of the formal class period. Students within the teams learn to depend on each other's unique skills and expertise (p. 276).

The third quality characteristic is the way the authors continually integrated the specified problem and literature surrounding the problem into the design of the course. Instead of only identifying the problem as a failure to attract and retain women in computing, Jessup et al. (2005) identified specific causes of the lack of women, including a lack of confidence, lack of mentoring, and the impersonal feel to the coursework and then explained how these causes were factored into the design of TC. Specifically, the authors discussed how participants' preference for teamwork led to the decision to have women work in groups, and that through this decision, the program negated a confidence loss more commonly experienced in women than in men. It also gave women a chance to form peer mentors. Most importantly, the authors described how working with local community members created a humanizing feel, which research shows women desire in a career (Jessup et al. 2005, pp. 274-276).

Preliminary support for the validity of evidence-bases scaled developed for this publication comes from the fact that the JWMSE publication, *Report From the Trenches* by Jessup et al. (2005), scored as exemplary using both a quantitative index and through additional qualitative analysis. Subsequent analysis during the qualitative phase of the mixed methods study confirmed the initial score of the publication as exemplary. Inductive coding of other qualities of the publication pointed to three additional qualities that warrant the designation as exemplary, all of which are related to what is traditionally found in an introduction or statement of the problem: (1) documentation was provided about how the course was designed based on recommendations from reports of other programs that had been proven to be successful, (2) the authors employed a theoretical framework, and (3) an explicit link was made between a problem and the solution.

4.4 Research Question 4: Additional Support for the Validity of the Scale Developed to Measure the Foundational Quality of Practice Oriented Publications

In the final step of the analysis, we returned to a quantitative or deductive approach to collect additional evidence that the foundational scale we developed was effective in distinguishing exemplary from non-exemplary publications. After using an inductive approach to identify additional characteristics of a practice-oriented article ranked as exemplary in overall quality by three raters independently, we sought to see if some of the same qualities would extend to other articles scoring high on the foundational scale. Confirmation of this hypothesis would support the validity of the scale and mean that we had moved closer to developing a way to measure the quality of practice-oriented publications.

To further test the effectiveness of the foundational scale in distinguishing high from low quality practice-oriented publications, the second and third author re-read all of the publications scoring a 5 or 6 on the foundational scale (n=24) and coded them for the absence or presence of each of the three additional dimensions of quality identified during the qualitative phase. All of these were part of what could be called problem formulation. The three qualities were: (1) documentation was provided about how the course was designed based on recommendations from reports of other programs that had been proven to be successful, (2) the authors employed a theoretical framework, and (3) an explicit link was made between a problem and the solution. Table 3 shows the results of this analysis.

Table 3. Presence of additional quality characteristics in top-scoring practice-oriented publications

Article #	Article ID Number	Quality 1	Quality 2	Quality 3
1	001_JWMSE99	X	X	X
2	013_JWMSE00		X	X
3	012_JWMSE01	X	X	
4	010_JWMSE03	X		X
5	009_JWMSE03	X	X	X
6	006_JWMSE03			X
7	016_JWMSE03		X	X
8	016_JWMSE05	X	X	X
9	007_JWMSE07	X		X
10	007_JWMSE09	X		X
11	013_JWMSE09	X	X	X
12	025_ASEE03	X		X
13	013_ASEE04	X	X	X
14	019_ASEE04	X	X	X
15	022_ASEE04		X	
16	024_ASEE04		X	X
17	009_ASEE05			X
18	008_ASEE05	X	X	X
19	019_ASEE06			X
20	022_ASEE07	X	X	X
21	028_ASEE07			X
22	012_ASEE07	X		X
23	034_ASEE07		X	X
24	012_ASEE08	X		X

The results shown in Table 3 demonstrate that the 24 articles scoring high on the foundational scale also generally shared three additional characteristics. Fifteen of 24 had described their projects as emerging from a pilot study; 14 of 24 described a theoretical foundation for their initiative; and 22 of 24 traced an explicit connection between the way the intervention was designed and their beliefs about the root causes of the historically long-standing under-representation of women in STEM fields.

5. Discussion and Conclusions

The analysis reported here is part of a larger project designed to identify trends over time in publications about gender and STEM. The focus of the analysis in this stage of the project was on practice-oriented publications. The principal overall conclusion from the analysis emerging from the first phase of this larger project is that majority of authors of practice-oriented articles failed to document that the decision made to implement a new program or activity was based on evidence. There was no convincing evidence that the quality of these publications has improved since 1995. This suggests that while well-meaning, many interventions designed to promote women's interest in STEM fields were launched without a strong foundation or understanding of the outcomes of similar initiatives in other settings.

We argue that practice-oriented publications and research publications have different purposes and, consequently, require a different set of standards to evaluate. Practice-oriented articles that appear in refereed venues are implicitly or explicitly put forward for replication as a way to design activities and programs that promote improvement in institutional practices and policies. While strong evaluations of the interventions can be hoped for, this kind of data does not lend itself to the more sophisticated analysis that would be expected of a research article appearing in a premiere outlet.

Open coding of a set of 24 articles scoring the highest on the foundational scale, demonstrates that these types of publications have their own set of characteristics that distinguish those that are exemplary that are quite distinct from what would be expected of a research article. The juxtaposition of the additional characteristics with the score on the foundational scale support the validity of the scale, particularly when used with other qualities that shape problem formulation. These criteria might be useful by editors and reviewers of practice-oriented publications. The list of qualities also can be helpful to novice researchers as they try to document the effectiveness of interventions they have designed. There is no reason they would not be generalizable to a non-STEM context.

One of the goals of the larger project is to use mixed methods to analyze quality dimensions of the literature that has been published on topics related to gender and interest and success in STEM majors and careers to see if there is a detectable shift toward more robust research designs and more evidence-based practice. The scale used in this research was developed to measure the extent that practice-oriented publications were evidence-based, in that they described activities or programs developed with a solid foundation of evidence from the literature about similar or related initiatives that had been proven to be effective. The argument for why this is important is that an initiative does not justify replication in other settings if it was not designed with a solid grounding in evidence. A second reason is that it is impossible to identify the contribution to knowledge or construct conclusions without relying on prior knowledge. (Beach, K. D., Becker, B. J., Kennedy, J. M., 2007) Programs or activities can have innovative components, even as they build on knowledge of related activities that have been proven effective.

The assessment of the quality of the foundational element of practice-oriented publications reported here offers a number of insights to scholars and practitioners setting out to write high-quality publications to showcase their efforts. The research reported here underscores the importance of being explicit about framing the publication in ways that document the source of the idea and in being explicit about linking the initiative to publications that preceded it. Would-be authors will enhance the credibility of their practice-oriented publications by doing the following:

- 1) Explicitly identify the source of the problem and its connection to the solution in theory and practice.
- 2) Describe how the program was designed with knowledge derived from previous research and explain how the program applied recommendations adopted from other programs with demonstrated effectiveness.
- 3) Detail broad and potential implications to practice and policy (e.g. course content, curriculum design).
- 4) Identify limitations and explain in what settings the intervention might not be effective.

The implications of relatively low average quality scores across the body of practice-oriented literature are worrisome for several reasons. One reason for this is that it is an indication that authors of practice-oriented publications often did not document that the selection of an activity was solidly grounded in knowledge that the intervention had the potential to be effective. A second reason is that it suggests that relevant literature, though readily accessible through electronic means, is not being incorporated in the design of new programs as frequently as would be expected. One repercussion of both of these to broadening participation in STEM is that it creates redundancy between publications. A second is that it suggests that there has been a significant investment of time, energy, and resources in perpetuating ideas that have not been documented to be effective in practice.

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