Cross-fertilization of STEM Education Communities

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There is considerable concern over the slow rate of dissemination of proven engineering education innovations (Borrego et al, 2010). One possible cause of the slow rate of dissemination is that engineering educators in different engineering disciplines seldom communicate with each other. To study this issue we analyzed the citations in all of the 2009 papers in the nine US engineering education journals and proceedings listed in Table 1. This guest editorial presents data for the *Journal of STEM Education, for the Proceedings of the ASEE Annual Meeting* and for the *Proceedings of the Frontiers in Education (FIE) Conference*. Results for other journals are published in the following companion guest editorials and forum: *Chemical Engineering Education* (Wankat, 2011c), *IEEE Transactions on Education* (Wankat, 2011b), *Journal of Engineering Education* (Wankat, 2011c), and *J. Professional Issues in Engineering Education and Practice* (Wankat, 2011d).

Data

Table 1 gives the grand totals of times that papers in each journal/proceedings were cited in a 2009 paper of one of the nine US journals/proceedings studied. Because there were only two issues of the *Journal of STEM Education* in 2009, both the 2009 and 2010 issues of *JSTEM Ed.* were analyzed.

Journal cited	# 2009 papers	# cits of this source	% all cits	% cits of sources studied	% same source cits	# self Cits in sources studied	% self cits
ASEE Proc.	1387	2256	6.6%	46.7%	86.3%	704	31.2%
J. Engr. Ed.	29	1209	3.5%	25.0%	20.4%	80	6.6%
FIE Proc.	128	683	2.0%	14.1%	21.5%	191	28.0%
IEEE Trans Ed.	67	252	0.7%	5.2%	52.4%	28	11.1%
Chem Engr Ed.	43	238	0.7%	5.0%	58.4%	38	16.0%
PRISM	--	75	0.2%	1.6%	0	0	0
ASCE J. Prof. Iss.	22	80	0.2%	1.7%	18.7%	23	28.7%
J. STEM Ed.	34	30	0.09%	0.6%	30.0%	10	33.3%
Advan Engr Ed.	11	8	0.02%	0.2%	0	1	12.5%

Table 1. Grand totals of times papers within a source (journal or proceedings) are cited in a 2009 paper (plus 2010 for *J. STEM Ed.*) The 1,721 papers in all the journals/proceedings studied had 34,080 citations, which is an average of 19.8 citations per paper. These 34,080 citations included 4,831 citations of the journals/proceedings studied (14.2% of total) and 1,075 of these 4,831 citations were self-citations (22.3%).

The second column in Table 1 lists the number of papers in 2009 in each journal/proceedings. The third column lists the number of times the listed source was cited in 2009 in the nine journals/proceedings studied. Division of the 2nd column by the 3rd column shows that the citations per paper are lowest in *J. STEM Ed.* and in *Advances in Engineering Education*—the two electronic journals studied. The fourth column lists the percentage of citations from these sources [e.g., *J. STEM Ed.* was cited 30 times which is 0.088% (rounded off to 0.09%) of the 34,080 citations]; the sum of these percentages does not add up to 100 because most of the citations were not of one of the nine journals/proceedings studied. The fifth column, which adds up to 100.0%, lists the percentage of citations from the journals/proceedings studied (e.g., the 30 citations of *J. STEM Ed.* in the 2009 issues of these nine journals/proceedings is 0.62% of the 4,831 citations of all nine journals/proceedings). Column six lists the percentage of papers cited that were cited from that source (e.g., 30% of the citations of *J. STEM Ed.* from the nine journals/proceedings studied were from papers in *J. STEM Ed.*). This column shows that the *ASEE Proceedings, IEEE Trans. Educ.*, and *Chem. Engr. Educ*. had the majority of their citations from themselves. Self citations are citations in which at least one author of the citing paper is also an author of the cited paper. Self citations are delineated separately because they do not necessarily indicate as wide reading of the literature as citations of work by others. Columns seven and eight list the number of self citations in the sources studied and the percentage of self citations, respectively [e.g., *J. STEM Ed.* had 10 self citations (33.3% of the 30 citations in *J. STEM Ed.*)].

The mission of the *Journal of STEM Education* covers all of STEM education and is not restricted to engineering education. Thus, the relatively low number of times *JSTEM Ed.* is cited in Table 1 probably underestimates the impact of the journal. Table 2 looks at citations from the opposite direction—which journals are cited by the papers in *JSTEM Ed.* The first nine journals/proceedings in Table 2 are the same as in Table 1. The additional 14 journals listed below include the papers from science, mathematics, and technology education journals cited in the 2009 and 2010 papers in *JSTEM Ed. J. STEM Ed.* authors are most likely to cite *J. Engr. Educ.* and *J. STEM Ed.* papers, but at rather low rates. It appears that there is roughly equal, but low coverage of the four STEM areas. However, the disciplinary engineering education journals (*IEEE Trans. Educ., Chem. Engr. Educ.*, and *J. Prof. Issues*) appear to be underrepresented, and 3 of the 4 citations of these journals are self-citations.

Journal cited	# citations in *J. STEM Ed.*	% of all citations in *J. STEM Ed.*	# self citations	% self citations
ASEE Proc.	7	1.0%	1	12.3%
J. Engr. Ed.	17	2.3%	2	11.8%
FIE Proc.	7	1.0%	5	71.4
IEEE Trans. Ed.	2	0.3%	1	50%
Chem Eng. Ed.	0	0	0	--
PRISM	0	0	0	--
J. Prof. Iss.	2	0.3%	2	100%
J. STEM Ed.	9	1.2%	3	33.3%
Advances Engr. Ed.	0	0	0	--
Science Educ.	6	0.8%	0	0
J. Ed. Technol Syst.	5	0.7%	1	20%
J. Rsch. Sci. T.	4	0.6%	0	0
Cell Biol. Ed.	3	0.4%	0	0
Desc. Sci. Innov. Ed.	3	0.4%	2	66.7%
Am. J. Phys.	2	0.3%	0	0
Educ. Technol.	2	0.3%	1	50%
J. Col. Sci. T.	2	0.3%	0	0
J. Ed. Comp. Rsch.	2	0.3%	0	0
J. Geosci. Ed.	2	0.3%	0	0
J. Sci. Teacher Ed.	2	0.3%	0	0
J. Chem. Ed.	1	0.1%	0	0
J. Rsch. Comp. Ed.	1	0.1%	0	0
J. Sci. T. Ed.	1	0.1%	0	0

Table 2. Summary of citations in 2009 and 2010 issues of *Journal of STEM Education: Innovations and Research.* The 34 papers in the *J. STEM Ed.* had 724 citations, which is an average of 21.3 citations per paper.

Table 3 shows the number of times papers from the 2009 issues of the journals/proceedings studied cite *J. STEM Ed.* papers. *PRISM* is not included in this analysis because *PRISM* papers usually do not cite references. As expected, the data for *J. STEM Ed.* is the same in Tables 2 and 3. In Table 3 *J. STEM Ed.* has the highest percentage of its citations from itself (1.2%). This pattern is usually true – journals are most likely to cite themselves. What stands out about *J. STEM Ed.* is that the percentage of citations from itself is the lowest of the journals and proceedings studied.

Journal/proceedings citing *J. STEM Ed.*	# citations of *J. STEM Ed.*	% of all citations in journal/proceedings	# self citations	% self citations
ASEE Proc.	14	0.08%	5	35.7%
J. Engr. Ed.	1	0.1%	1	100%
FIE Proc.	5	0.3%	1	20%
IEEE Trans. Ed.	0	0	0	--
Chem. Eng. Ed.	1	0.3%	0	0
J. Prof. Iss.	2	0.3%	2	100%
J. STEM Ed.	9	1.2%	3	33.3%
Advances Engr. Ed.	0	0	0	--

Table 3. Number of times *J. STEM Ed.* papers are cited in 2009 papers (plus 2010 for *J. STEM Ed*) in the journals/proceedings studied.

How do the other journals/proceedings studied compare to *J. STEM Ed.*? The results for the *Proceedings of the ASEE Annual Meeting* are shown in Tables 4 and 5, and the results for the *Proceedings of the Frontiers in Education Conference* are shown in Tables 6 and 7.

Journal/proceedings cited by *ASEE Proc.*	# citations in *ASEE Proc.*	% of all citations in *ASEE Proc.*	# self citations	% self citations
ASEE Proc.	1947	11.4%	622	31.9%
JEE	745	4.3%	45	6.0%
FIE Proc.	426	2.5%	103	24.2%
IEEE Trans.	87	0.5%	12	13.8%
Chem. Engr. Ed.	78*	0.5%	7	9.0%
PRISM	64	0.4%	0	0
J. Prof .Iss.	54	0.3%	15	27.8%
J. STEM Ed.	14	0.08%	5	35.7%
Advances Engr. Ed.	6	0.04%	1	16.6%

Table 4. Summary of Citations in *Proceedings of the 2009 ASEE Annual Meeting.* The 1,387 papers in the *Proceedings* had 17,142 references, which is an average of 12.4 citations per paper.

Table 4 gives the results for the *Proceedings of the 2009 ASEE Annual Meeting*. The 1,387 papers and the 17,142 citations dwarf the numbers from the other sources, which makes this *Proceedings* the most popular place for engineering professors to present their educational results. Most of these papers are presented in the ASEE divisions based on different engineering and engineering technology disciplines, although a significant number occur in a more engineering education oriented disciplinary division (mainly Educational Research and Methods). A significant number of papers cite only technical references and do not include any educational references. Clearly, the most-cited educational source in the *ASEE Proceedings* was the *ASEE Proceedings*. Another way of looking at this not shown in Table 4 is that 633 papers (45.6% of all papers) cited the *ASEE Proceedings* at least once and 373 papers had a self-citation to the *ASEE Proceedings*. Thus, 58.9% of the papers that cited the *ASEE Proceedings* included a self citation to the *ASEE Proceed-*

ings. One interpretation of this result is that since all attendees at the ASEE Annual meeting receive a CD of the Proceedings, it is easier for former attendees to read and cite papers from the Proceedings than those who never attended an ASEE meeting. If their topic is similar to their earlier paper, it is natural for authors to cite their own work. Since the ASEE Annual meeting has a number of repeat attendees every year, the result is a large number of citations and self citations of the *ASEE Proceedings* from previous years. Note that the self citation numbers are probably undercounted because some papers are listed in the references as "Smith et al," and we did not check for self-citing of the other authors included in the et al.

Table 5 shows the number of times papers from the 2009 journals/proceedings studied, excluding *PRISM*, cited *ASEE Proceedings* papers. As expected, the data for *ASEE Proceedings* is the same in Tables 4 and 5. In Table 5 *ASEE Proceedings* has the highest percentage of its citations from itself (11.4%). What stands out about *ASEE Proceedings* is that the percentages of self citations from all the journals/proceedings are relatively high.

Journal citing *ASEE Proc.*	# citations of *ASEE Proc*	% of all citations in *ASEE Proc.*	# self citations	% self citations
ASEE Proc.	1947	11.4%	622	31.9%
JEE	55	3.9%	12	21.8%
FIE Proc.	94	5.5%	32	34.0%
IEEE Trans. Ed.	26	1.9%	7	26.9%
Chem. Engr. Ed.	35	4.0%	8	22.9%
J. Prof. Iss.	13	2.3%	11	84.6%
J. STEM Ed.	7	1.0%	1	12.3%
Advances Engr. Ed.	29	9.9%	11	37.9%

Table 5. Number of times *Proceedings of the ASEE Annual Meeting* papers are cited in 2009 papers (plus 2010 for *J. STEM Ed.*) in the journals/proceedings studied.

Citation analysis for the *FIE Proceedings* (Table 6) shows that the *FIE Proceedings* contains the second largest number of papers and second largest number of citations. The *FIE Proceedings* are the most cited source in the *FIE Proceedings*, and there are 47.6% self citations of the *FIE Proceedings*, which is very high. Using the same alternate lens used for the *ASEE Proceedings* for the *FIE Proceedings*, 65 papers (50.8% of all papers) cited the *FIE Proceedings* at least once and 45 papers had a self citation to the FIE Proceedings. Thus, 69.2% of the papers that cited the *FIE Proceedings* included a self citation to the *FIE Proceedings*. The rationale used to explain the similar phenomenon for

Journal cited by *FIE Proceedings*	# citations in *FIE Proceedings*	% of all citations in *FIE Proceedings*	# self citations	% self citations
ASEE Proc.	94	5.5%	32	34%
JEE	94	5.5%	2	2.1%
FIE Proc.	147	8.6%	70	47.6%
IEEE Trans. Ed.	22	1.3%	1	4.5%
Chem. Engr. Ed.	5	0.3%	0	0
PRISM	4	0.2%	0	0
J. Prof. Iss.	1	0.1%	0	0
J. STEM Ed.	5	0.3%	1	20%
Advances Engr. Ed.	2	0.1%	0	0

Table 6. Summary of citations in *2009 FIE Proceedings*. The 128 papers in the *FIE Proceedings* had 1,701 references, which is an average of 13.3 citations per paper.

the *ASEE Proceedings* is probably appropriate here as well. The *ASEE Proceedings* also receives a significant number of self citations in the *FIE Proceedings*. *JEE* received a significant number of citations with very few self citations. Since FIE is cosponsored by IEEE, a large number of electrical engineering professors attend the conference. Thus, the relatively high number of citations of the *IEEE Transactions on Education* compared to the other disciplinary engineering education journals is not surprising. The number of citations of the other journals is quite small.

Table 7 shows the number of times papers from the 2009 journals/proceedings studied, excluding *PRISM*, cited *FIE Proceedings* papers. *FIE Proceedings* has the highest percentage of its citations from itself (8.6%). Although there is a significant percentage of self citations of the *FIE Proceedings* in *FIE Proceedings* papers, the total percentage of self citations (28.0%, shown in Table 1) is less than for *ASEE Proceedings* (31.2%). Perhaps this difference is due to the ready availability of *FIE Proceedings* on the internet.

Journal citing *FIE Proceedings*	# citations of *FIE Proceedings*	% of all citations in *FIE Proceedings*	# self citations	% self citations
ASEE Proc.	426	2.5%	103	24.2%
JEE	29	2.1%	5	17.2%
FIE Proc.	147	8.6%	70	47.6%
IEEE Trans. Ed.	50	3.6%	3	6.0%
Chem. Engr. Ed.	10	1.2%	4	40.0%
J. Prof. Iss.	3	0.5%	0	0%
J. STEM Ed.	7	1.0%	5	71.4%
Advances Engr. Ed.	11	3.8%	1	9.1%

Table 7. Number of times *FIE Proceedings* papers are cited in 2009 papers (plus 2010 for *J. STEM Ed.*) in the journals/proceedings studied.

This data and the data reported elsewhere (Wankat, 2011 a,b,c,d) shows that papers in the disciplinary engineering education journals are not citing papers from the proceedings, the engineering education research journals, or the broader STEM education journals; and the papers from the disciplinary engineering education journals are not being cited by the other journals. Thus, there is limited cross-fertilization of engineering education research and development, which clearly limits dissemination of results. This is exactly the behavior we would expect if there are "silos" in engineering education. The same conclusion may be true for other areas of STEM education, but this study did not collect the data necessary to support that hypothesis. The design of *J. STEM Ed.* will help to encourage communication between silos, but the journal has not appeared to have significant impact beyond its readers and authors.

Recommendations

What can we do to control this tendency to form silos and to increase the rate of dissemination of effective educational innovations in the STEM disciplines? None of the engineering or science education journals have a wide enough readership that they can unilaterally solve the problems caused by lack of cross-fertilization and low rates of dissemination, which are indicated by the lack of cross-citing. Thus, similar editorials—but with data and recommendations specific to each journal—are being published in engineering education journals (Wankat, 2011 a,b,c,d).

The following recommendations are suggested for *J. STEM Ed.*:

1. Very simply(though it is hard to put into practice), we need to read, talk, and listen to each other. Then we need to communicate to others what we have learned. This is particularly difficult for *J. STEM Ed*. because its community includes all of STEM.
2. Jargon can be useful for rapidly and clearly communicating complex ideas; however, jargon also often serves as a barrier to access to the information. Because of the broad range of articles published in *J. STEM Ed.*, it is important that authors continue to minimize jargon, and where the jargon is necessary it should be clearly defined in terms that non-experts can understand. One approach to explaining terms is illustrated by Felder et al (2011).
3. The authors and readers of *J. STEM Ed.* should very strongly encourage all potential and new STEM professors to take a how-to-teach course as graduate students or to take such a course or workshop during their first year on

the job (Felder et al., 2011; Wankat, 1999). This will not only improve teaching, but will also make new professors more aware, increase their understanding of the STEM education research literature and, in many cases, make them more willing to adopt proven innovations. A major selling point for new faculty at research universities is the requirement for an Education section in NSF Career proposals.

4. STEM educators who are familiar with advanced pedagogical methods grounded in rigorous educational research should volunteer to teach the how-to-teach courses discussed in recommendation #3.
5. The journal should develop venues for "gate keepers" who are familiar with the broad range of STEM education and STEM education literature and can bring this information to the readers who have a more disciplinary orientation. Current examples of effective gate keeping in engineering education are Prof. Richard Felder's column "Random Thoughts" in *Chemical Engineering Education* and "The Academic Bookshelf" in *JEE*. Another model that *J. STEM Ed.* could use is the "*JEE* Selects" feature in *PRISM*, except by featuring one article in each issue from one of the other STEM education journals.
6. Authors of *J. STEM Ed.* papers should be strongly encouraged by reviewers and editors to read and cite appropriate papers from other STEM education journals/proceedings.
7. The editors/associate editors of all the engineering education journals should meet to plan strategies for what the journals can do to improve engineering education.
8. The *J. STEM Ed.* should continue to emphasize its strengths: publishing papers from all of STEM, immediate availability free on the internet, and a focus on case studies.

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