

Current Comments®

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The Role of Undergraduate Colleges in Research. Part 1. Highest Output, Most-Cited, and Highest Impact Institutions, 1981-1992

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Abstract

A citation analysis of research publications of 74 primarily liberal arts colleges, based on 14,510 ISI®-indexed papers published and cited from 1981 through 1992, is presented. Part 1 of this essay identifies the highest output, most-cited, and highest impact colleges in all fields of science. Separate impact rankings in the life sciences, agriculture and biology, and clinical medicine are also included. Part 2 will identify the highest impact colleges in the physical and chemical sciences as well as engineering and technology. In addition, their highest impact papers will be identified.

Introduction

In April I participated in a meeting co-sponsored by the Council on Undergraduate Research (CUR) and the National Institutes of Health (NIH) entitled "Dialogue with NIH and NSF."¹ Founded in 1978, CUR is a nonprofit association of 600 primarily undergraduate colleges and universities with 2,000 member teachers, administrators, and researchers. Its purpose is to promote and provide information on scientific research at the nation's primarily liberal arts colleges.

It has been several years since we discussed in *Current Contents*® (CC®) the contribution of undergraduate colleges to research.² And that essay focused on their role as a major "pipeline" of the nation's future science graduate and doctoral students. However, the CUR meeting gave us the opportunity to do something different—that is, to provide a citationist perspective on scientific research conducted at undergraduate colleges.

The data we prepared demonstrated that liberal arts colleges have a significant impact as research institutions. This aspect of their overall contribution to the nation's sci-

ence base has not been appreciated and deserves wider recognition.

Undergraduate Colleges: A Key Pipeline of Research Scientists

It has been well documented that liberal arts colleges are an important training ground for students who go on to earn graduate and doctoral science degrees. Indeed, certain select liberal arts colleges have produced a disproportionate share of science graduates and PhDs, compared with larger comprehensive universities having more extensive science curricula, better-equipped labs, and far greater levels of research funding.

These findings were extensively documented in the 1985 and 1987 Oberlin reports on the role of liberal arts colleges in educating America's scientists.^{3,4} The reports focused on 50 so-called "science active" colleges. They demonstrated that these smaller, primarily undergraduate institutions ranked among the leaders on a variety of criteria—baccalaureates who went on to earn PhDs in mathematics, physical sciences, life sciences, and other fields; membership in the National Academy of

Table 1: Primarily undergraduate liberal arts colleges included in the study. Asterisks indicate those included in the original Oberlin Group reports (see references 3 and 4).

*Albion Coll. Albion, MI	*DePauw Univ. Greencastle, IN	*Middlebury Coll. Middlebury, VT
Allegheny Coll. Meadville, PA	Dickinson Coll. Carlisle, PA	Montclair State Coll. Upper Montclair, NJ
*Alma Coll. Alma, MI	*Earlham Coll. Richmond, IN	*Mt. Holyoke Coll. South Hadley, MA
*Amherst Coll. Amherst, MA	Fort Lewis Coll. Durango, CO	*Oberlin Coll. Oberlin, OH
*Antioch Coll. Yellow Springs, OH	*Franklin & Marshall Coll. Lancaster, PA	*Occidental Coll. Los Angeles, CA
Augustana Coll. Rock Island, IL	*Grinnell Coll. Grinnell, IA	*Ohio Wesleyan Univ. Delaware, OH
*Barnard Coll. New York, NY	*Hamilton Coll. Clinton, NY	*Pomona Coll. Claremont, CA
*Bates Coll. Lewiston, ME	*Hampton Univ. Hampton, VA	*Reed Coll. Portland, OR
*Beloit Coll. Beloit, WI	*Harvey Mudd Coll. Claremont, CA	Rhodes Coll. Memphis, TN
Birmingham Southern Coll. Birmingham, AL	*Haverford Coll. Haverford, PA	Skidmore Coll. Saratoga Springs, NY
*Bowdoin Coll. Brunswick, ME	Hendrix Coll. Conway, AR	*Smith Coll. Northampton, MA
*Bryn Mawr Coll. Bryn Mawr, PA	Hobart & Wm. Smith Coll. Geneva, NY	*St. Olaf Coll. Northfield, MN
*Bucknell Univ. Lewisburg, PA	*Hope Coll. Holland, MI	*Swarthmore Coll. Swarthmore, PA
Calvin Coll. Grand Rapids, MI	Ithaca Coll. Ithaca, NY	*Trinity Coll. Hartford, CT
*Carleton Coll. Northfield, MN	Juniata Coll. Huntingdon, PA	*Union Coll. Schenectady, NY
Colby Coll. Waterville, ME	*Kalamazoo Coll. Kalamazoo, MI	Ursinus Coll. Collegeville, PA
*Colgate Univ. Hamilton, NY	*Kenyon Coll. Gambier, OH	*Vassar Coll. Poughkeepsie, NY
Coll. Charleston Charleston, SC	Knox Coll. Galesburg, IL	*Wabash Coll. Crawfordsville, IN
*Coll. Holy Cross Worcester, MA	*Lafayette Coll. Easton, PA	*Wellesley Coll. Wellesley, MA
Coll. William & Mary Williamsburg, VA	Lewis & Clark Coll. Portland, OR	*Wesleyan Univ. Middletown, CT
*Coll. Wooster Wooster, OH	Luther Coll. Decorah, IA	Westmont Coll. Santa Barbara, CA
*Colorado Coll. Colorado Springs, CO	Lycoming Coll. Williamsport, PA	*Wheaton Coll. Wheaton, IL
Connecticut Coll. New London, CT	*Macalester Coll. St. Paul, MN	*Whitman Coll. Walla Walla, WA
*Davidson Coll. Davidson, NC	*Manhattan Coll. Bronx, NY	*Williams Coll. Williamstown, MA
*Denison Univ. Granville, OH	Mary Washington Coll. Fredericksburg, VA	

Sciences; NSF grantees; the 1,000 most-cited scientists of 1965-1978;⁵ and so on.

More recently, the 1991 Project Kaleidoscope analysis has confirmed these findings and extended them beyond the 50 institutions in the Oberlin Group.⁶ Supported by the NSF and private foundations, the analysis ranked US institutions both by absolute number and proportion of graduates receiving bachelor's degrees in a variety of scientific fields. The results consistently showed that liberal arts colleges ranked high in producing a substantial number of research scientists.

The Oberlin and Kaleidoscope reports, as well as other published studies,^{7,8} provide a wealth of quantitative and qualitative data on the *pipeline* value of undergraduate colleges to US science. Typically, this success is attributed to the students' hands-on experience in actual research projects under faculty mentors. As an important source of the nation's future research professionals, select liberal arts colleges ought to receive NSF and NIH funding at a *size-adjusted* level at least comparable to the leading comprehensive research universities.

But there are other critical roles that colleges play in US research. For example, liberal arts colleges also contribute to advances in scientific knowledge. While the faculty are committed to teaching, they also do research and publish review articles. As the data presented below indicate, select liberal arts colleges have a substantial impact in the international scientific literature.

The Impact of Undergraduate Colleges on Research

ISI®'s databases are uniquely suited to indicate this impact in quantitative terms. They include bibliographic information on about 15 million papers published in thousands of journals since 1945, and more than 215 million references they cited. From these data, one can derive rankings of in-

stitutions in terms of number of papers, citations, average citations per paper, proportion of papers actually cited, and so on. Keep in mind that the data cover all fields of science as well as the social sciences and the arts and humanities. This study focuses on the sciences, but it should be stressed that liberal arts colleges no doubt have even greater impact in the social sciences and humanities.

The following analysis is based on 74 undergraduate institutions shown in Table 1. All of the 50 institutions participating in the Oberlin Report have been included and are indicated by asterisks. But the Project Kaleidoscope report shows that many other liberal arts colleges rank high in terms of producing science graduates. Thus, 24 additional institutions that were not among the original Oberlin Group have also been included. They were selected on the basis of their CUR membership—each had at least five individual members. Many of them have appeared in the Project Kaleidoscope rankings of leading producers of science graduates in various fields.

In the 1981-1992 *Science Citation Index*® (SCI®) database, these 74 colleges produced 14,500 papers which received about 90,000 citations. Thus, dividing numbers of citations by papers, the average 12-year impact for the CUR colleges was 6.2.

Highest Output and Most-Cited Colleges

Table 2 lists 25 institutions that produced at least 200 papers. The College of William & Mary had the highest output with about 1,500 papers. Wesleyan University is the only other institution that produced over 1,000 papers.

It is interesting that the College of William & Mary was *not* among the original Oberlin Group institutions. The only other non-Oberlin Group institution on this list is Ithaca College, with 287 papers.

Table 3 lists 25 institutions that received at least 1,300 citations to their 1981-1992

Table 2: Highest output liberal arts colleges, 1981-1992 *SCI*®.

Rank	Institution	1981-92 Papers	1981-92 Cites	12-Yr. Impact
1.	Coll. Wm. & Mary	1471	11,326	7.7
2.	Wesleyan Univ.	1003	7688	7.7
3.	Wellesley Coll.	476	5212	11.0
4.	Amherst Coll.	450	3683	8.2
5.	Lafayette Coll.	432	1908	4.4
6.	Bryn Mawr Coll.	429	2565	6.0
7.	Williams Coll.	415	2528	6.1
8.	Bucknell Univ.	402	1513	3.8
9.	Vassar Coll.	383	2374	6.2
10.	Smith Coll.	361	2624	7.3
11.	Swarthmore Coll.	340	1857	5.5
12.	Colgate Univ.	338	1883	5.6
13.	Occidental Coll.	332	2174	6.6
14.	Oberlin Coll.	326	1729	5.3
15.	Franklin & Marshall	321	1910	6.0
16.	Trinity Coll.	311	1390	4.5
17.	Manhattan Coll.	307	1936	6.3
18.	Pomona Coll.	293	2538	8.7
19.	Ithaca Coll.	287	2912	10.2
20.	Harvey Mudd Coll.	277	1031	3.7
21.	Hope Coll.	271	1887	7.0
22.	Reed Coll.	263	1750	6.7
23.	Barnard Coll.	235	2093	8.9
24.	Coll. Holy Cross	231	1339	5.8
25.	Mt. Holyoke Coll.	222	1543	7.0

papers. Not surprisingly, the College of William & Mary ranks first with over 11,300 citations. Typically, lists of institutions ranked by output and total citations tend to overlap significantly. For example, 23 of the 25 most-cited colleges also ranked among the highest output institutions. The two exceptions are Haverford College (2,094 citations) and Middlebury College (1,319).

Highest Impact Colleges: All Science Fields

The highest impact colleges are shown in Table 4, including 27 institutions with a 12-year impact of at least 5.5. The list includes only those institutions that produced at least 100 papers. This effectively "censors" the occasional citation "outlier"—an institution that achieves high impact based on a few highly cited papers. By setting an arbitrary threshold of 100 papers, the list

Table 3: Most-cited liberal arts colleges, 1981-1992 *SCI*®.

Rank	Institution	1981-92 Cites	1981-92 Papers	12Yr. Impact
1.	Coll. Wm. & Mary	11,326	1471	7.7
2.	Wesleyan Univ.	7688	1003	7.7
3.	Wellesley Coll.	5212	476	11.0
4.	Amherst Coll.	3683	450	8.2
5.	Ithaca Coll.	2912	287	10.2
6.	Smith Coll.	2624	361	7.3
7.	Bryn Mawr Coll.	2565	429	6.0
8.	Pomona Coll.	2538	293	8.7
9.	Williams Coll.	2528	415	6.1
10.	Vassar Coll.	2374	383	6.2
11.	Occidental Coll.	2174	332	6.6
12.	Haverford Coll.	2094	187	11.2
13.	Barnard Coll.	2093	235	8.9
14.	Manhattan Coll.	1936	307	6.3
15.	Franklin & Marshall	1910	321	6.0
16.	Hope Coll.	1887	271	7.0
17.	Colgate Univ.	1883	338	5.6
18.	Swarthmore Coll.	1857	340	5.5
19.	Reed Coll.	1750	263	6.7
20.	Oberlin Coll.	1729	326	5.3
21.	Mt. Holyoke Coll.	1543	222	7.0
22.	Bucknell Univ.	1513	402	3.8
23.	Trinity Coll.	1390	311	4.5
24.	Coll. Holy Cross	1339	231	5.8
25.	Middlebury Coll.	1319	178	7.4

includes institutions that were consistently productive over the 12-year period.

The table also shows the average impact of all 74 CUR institutions combined as well as the so-called "world average"—that is, the average impact for the entire *SCI*® file. They are shown in italics.

It should be noted that the CUR average impact of 6.2 is higher than the world average of 5.5. That is, the average CUR paper was cited more frequently than the average *SCI* paper. This alone is an interesting indicator of the contribution of liberal arts colleges to research.

In fact, all 27 institutions met or exceeded the world average impact. And two colleges *doubled* the world average—Haverford (11.2) and Wellesley (11.0). Clearly, these primarily undergraduate institutions make a significant contribution to research. The number of their papers may be small compared to the comprehensive research

Table 4: Highest impact liberal arts colleges in all fields of science, 1981-1992 *SCI*[®], which published at least 100 papers.

Rank	Institution	12-Yr. Impact	1981-92 Papers	1981-92 Citations
1.	Haverford Coll.	11.2	187	2094
2.	Wellesley Coll.	11.0	476	5212
3.	Ithaca Coll.	10.2	287	2912
4.	Ohio Wesleyan	9.5	108	1021
5.	Barnard Coll.	8.9	235	2093
6.	Pomona Coll.	8.7	293	2538
7.	Amherst Coll.	8.2	450	3683
8.	Coll. Wm. & Mary	7.7	1471	11,326
	Wesleyan Univ.	7.7	1003	7688
10.	Middlebury Coll.	7.4	178	1319
11.	Smith Coll.	7.3	361	2624
12.	Hope Coll.	7.0	271	1887
	Mt. Holyoke Coll.	7.0	222	1543
14.	Reed Coll.	6.7	263	1750
15.	Occidental Coll.	6.6	332	2174
16.	Manhattan Coll.	6.3	307	1936
17.	Vassar Coll.	6.2	383	2374
	<i>CUR AVG.</i>	6.2	14,510	89,892
18.	Williams Coll.	6.1	415	2528
19.	Bryn Mawr Coll.	6.0	429	2565
	Franklin & Marshall	6.0	321	1910
21.	Colorado Coll.	5.9	190	1112
22.	Coll. Holy Cross	5.8	231	1339
23.	Colgate Univ.	5.6	338	1883
24.	Coll. Wooster	5.1	154	777
25.	Bates Coll.	5.5	118	643
	Carleton Coll.	5.5	155	844
	Swarthmore Coll.	5.5	340	1857
	<i>WORLD AVG.</i>	5.5	7,718,263	42,280,424

universities. But their impact equals or exceeds the average citation frequency of all *SCI* papers.

Keep in mind that the average impact of US papers is higher than the world average. Thus, the *CUR* average may not compare as favorably against it as the world average, and fewer colleges may equal or exceed the US average.

The data shown here are for all of science as a whole. Of course, certain liberal arts colleges may specialize or excel in a particular research area, such as the life sciences or chemistry or engineering. Thus, different sets of colleges might be identified in field-specific impact rankings. This essay presents impact rankings in the life

Table 5: Highest impact liberal arts colleges in the life sciences, 1981-1992 *SCI*[®], which published at least 50 papers.

Rank	Institution	12-Yr. Impact	1981-92 Papers	1981-92 Citations
1.	Wellesley Coll.	16.0	242	3861
2.	Pomona Coll.	12.3	140	1716
3.	Amherst Coll.	11.2	240	2693
4.	Barnard Coll.	11.1	126	1393
5.	Mt. Holyoke Coll.	9.6	90	860
6.	Oberlin Coll.	9.1	72	655
7.	Williams Coll.	8.9	161	1435
	<i>WORLD AVG.</i>	8.2	3,404,992	27,758,805
8.	Wesleyan Univ.	8.1	532	4320
9.	Coll. Wooster	7.8	61	477
	Ithaca Coll.	7.8	61	474
	Smith Coll.	7.8	136	1064
12.	Hope Coll.	7.4	156	1153
	Reed Coll.	7.4	165	1214
14.	Colgate Univ.	7.3	100	732
	<i>CUR AVG.</i>	7.2	5449	39,438
15.	Middlebury Coll.	7.1	54	385
	Swarthmore Coll.	7.1	132	940
17.	Occidental Coll.	6.8	154	1043
18.	Vassar Coll.	6.6	224	1468
19.	Franklin & Marshall	6.1	115	700
20.	Harvey Mudd Coll.	5.9	79	462
21.	Haverford Coll.	5.8	55	321
22.	Bowdoin Coll.	5.7	54	305
23.	Coll. Wm. & Mary	5.5	225	1227
24.	Bryn Mawr Coll.	5.1	183	939
	Colby Coll.	5.1	74	375

sciences, agriculture and biology, and clinical medicine. In part 2, rankings in the physical and chemical sciences as well as engineering and technology will be presented. In addition, the most-cited papers from the liberal arts colleges will be examined in part 2.

These field categories are defined by the journal groupings in *Current Contents*[®]. These groupings have some redundancy—i.e., overlap in journal coverage. For example, the *Journal of the American Chemical Society* is covered in two editions of *CC*[®]—the physical/chemical sciences as well as the life sciences. However, this overlap is consistent for all institutions in the database.

Table 6: Highest impact liberal arts colleges in the agricultural and biological sciences, 1981-1992 *SCJ*®, which published at least 50 papers.

Rank	Institution	12-Yr. Impact	1981-92 Papers	1981-92 Citations
1.	Smith Coll.	10.9	58	634
2.	Reed Coll.	10.7	76	816
3.	Manhattan Coll.	9.9	139	1381
4.	Swarthmore Coll.	8.1	91	737
5.	Occidental Coll.	8.0	181	1445
6.	Barnard Coll.	7.9	49	389
7.	Williams Coll.	7.5	84	628
8.	Oberlin Coll.	6.9	82	562
9.	Pomona Coll.	6.3	64	402
10.	Wesleyan Univ.	6.2	86	530
11.	Colgate Univ.	5.8	61	352
12.	Connecticut Coll.	5.7	77	435
13.	Amherst Coll.	5.6	55	308
14.	Coll. Wm. & Mary	5.5	499	2740
	<i>CUR AVG.</i>	5.3	3655	19,452
15.	Franklin & Marshall	5.2	69	358
16.	Mt. Holyoke Coll.	5.0	64	318
17.	Wellesley Coll.	4.7	62	293
	<i>WORLD AVG.</i>	4.7	1,122,706	5,264,385
18.	Bucknell Univ.	4.4	101	441
	Colby Coll.	4.4	51	223
	Colorado Coll.	4.4	62	275
21.	Vassar Coll.	4.1	100	413
22.	Ithaca Coll.	3.8	57	214
23.	Lafayette Coll.	3.6	164	597
24.	Bowdoin Coll.	3.2	52	165
25.	Bryn Mawr Coll.	2.4	65	158

Impact Rankings in the Life Sciences

Table 5 includes 25 institutions that produced at least 50 life sciences papers and achieved an impact of at least 5.0.

The average *CUR* impact in the life sciences (7.2) is less than the world average (8.2). This field includes molecular biology, genetics, and many other specialties involving sophisticated laboratories and equipment. Many of the smaller liberal arts colleges may not have the requisite facilities and are thus underrepresented in these high impact specialties. But in all other fields, the *CUR* average impact is higher than the world average, as will be seen.

Fourteen institutions exceeded the *CUR* average and, of these, seven also exceeded the world average. Four colleges had im-

Table 7: Highest impact liberal arts colleges in clinical medicine, 1981-1992 *SCJ*®, which published at least 15 papers.

Rank	Institution	12-Yr. Impact	1981-92 Papers	1981-92 Citations
1.	Wellesley Coll.	9.5	56	531
2.	Smith Coll.	8.5	19	162
3.	Barnard Coll.	5.4	29	156
	<i>CUR AVG.</i>	4.9	585	2882
4.	Bryn Mawr Coll.	4.8	43	206
5.	Trinity Coll.	4.4	43	190
	<i>WORLD AVG.</i>	4.4	1,932,143	8,560,837
6.	Pomona Coll.	4.3	16	68
7.	Wesleyan Univ.	4.1	15	62
8.	Vassar Coll.	3.4	46	158
9.	Coll. Wm. & Mary	2.3	17	39
	Wheaton Coll.	2.3	15	35
11.	Ithaca Coll.	1.3	32	43

pacts greater than 10.0—Wellesley (16.0), Pomona (12.3), Amherst (11.2), and Barnard (11.1).

Impact Rankings in Agricultural and Biological Sciences

Table 6 shows 25 institutions that produced at least 50 papers in the agricultural and biological sciences with an impact of 2.4. Following the *CC*® journal groupings, the agricultural and biological sciences include agronomy, plant sciences, aquatic, and environmental science.

The impact of the average *CUR* paper in this field (5.3) is higher than the world average (4.7). And 17 institutions met or exceeded the world average. The impact of three colleges was double the world average—Smith (10.9), Reed (10.7), and Manhattan College (9.9).

Impact Rankings in Clinical Medicine

Only 11 liberal arts colleges produced at least 15 papers in clinical medicine, as shown in Table 7. This should not be surprising because clinical research typically requires the facilities of a medical school or teaching hospital. Very few of the undergraduate colleges in this analysis are affiliated with a medical school or hospital.

Thus, the institutions shown here no doubt were involved in collaborative clinical studies with medical universities. Indeed, collaboration with large research universities is probably a common feature of research at liberal arts colleges. This will be illustrated when we examine their most-cited papers in part 2 of this essay.

It is interesting that the CUR average impact in clinical medicine (4.9) is still higher than the world average (4.4). And five colleges equaled or exceeded the world average. Of these, the impact of Wellesley College (9.5) was double the world average.

Keep in mind that we are dealing with comparatively small numbers of papers here. For example, Wesleyan and Wheaton each produced only 15 clinical medicine papers. At this level, just one or a few highly cited papers can significantly influence an institution's overall impact.

Conclusion

In conclusion, for the group of 74 CUR member institutions, the data show that se-

lect liberal arts colleges make a significant contribution to US research. Over a third of these institutions exceeded the world average impact in all fields of science. And with the exception of the life sciences, the average CUR paper was cited more frequently than the world average in agricultural and biological sciences as well as clinical medicine. Several colleges even doubled the world averages—Manhattan, Reed, Smith, and Wellesley.

In part 2, we'll identify the highest impact liberal arts colleges in the physical and chemical sciences as well as engineering and technology. In addition, their most-cited papers from 1981 to 1992 will be presented. As noted earlier, these high impact papers typically are collaborative research efforts involving large research universities. Thus, a separate list of high impact papers *solely* from the liberal arts colleges will also be presented.

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