

GEOSCIENCE RESEARCH AT LIBERAL ARTS COLLEGES: SCHOOL RANKINGS

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ABSTRACT

Liberal arts colleges have in recent years placed an increasing emphasis on research. In this environment of increased interest in research at liberal arts colleges we present a ranking of research in geoscience at national liberal arts colleges based upon articles published in GeoRef listed journals. We find that the research activity is highly concentrated among a few schools. We also find that liberal arts faculty are interested in teaching geoscience as measured by the number of publications in the Journal of Geoscience Education and that there is a positive correlation between faculty research at an institution and the undergraduates who go on to receive Ph.D.'s in geoscience.

Keywords: Education - Undergraduate.

INTRODUCTION

Recent work by McCaughey (1994) suggests that the faculty of liberal arts colleges have increasingly viewed themselves as scholars as well as teachers. McCaughey (1994) reports nearly half of the liberal arts faculty he surveyed indicated that "their primary interests leaned more toward research [than toward teaching]," and that ninety percent believed it was difficult to attain tenure without research. This change in perception is likely to be true for faculty in geoscience departments as well as in other fields. Geoscience department web-pages at liberal arts colleges routinely report on the publications of their faculty. In addition, liberal arts colleges themselves frequently tout the scholarly activity of their faculty. Wesleyan University identifies "the University's mission as a twofold one, the parts inseparable: to advance knowledge and to educate students to be active, self-aware, critical, and responsible citizens of the complex world they will soon inherit." It then asserts that in meeting this mission, "The primacy of the role of the teacher-scholar, the synergy of teaching and research, sets the keen and demanding intellectual culture of Wesleyan apart from its peers." And Oberlin College maintains the following: "Oberlin professors are simultaneously scholars and teachers. Like the professors at major research universities, they devote their entire careers to making important contributions to their disciplines through writing and research."

This environment of increased interest in the research of faculty at liberal arts colleges is the background for our study. This paper presents evidence of the amount of geoscience research at national liberal arts colleges. In particular we present departmental rankings, a measure of the concentration of research among schools, an examination of the increase in scholarship over time, a look at the journals in which liberal arts faculty publish, and an examination of the fields of inquiry by liberal arts faculty. In many ways, this study is a natural extension of McCaughey's work. McCaughey's study was limited to 24 schools and looked only at the social sciences and humanities as a whole. Our study is a much more extensive examination of the research output in a single field, in the sciences, and among a broader set of colleges. We can thus address important questions that McCaughey leaves unanswered: to what extent has the changing ethos at the top liberal arts colleges permeated other liberal arts colleges? To what extent are the patterns McCaughey found also evident in the sciences and geoscience departments in particular? The present study complements similar studies examining research publication in other fields by liberal arts college faculty (Bodenhorn, 1997; Hartley and Robinson, 1997; Schmauder et al., 1999).

Given the interest in research at liberal arts colleges, there is a need for some benchmark to which schools can compare themselves, because it may be unrealistic to evaluate the research productivity of liberal arts colleges by the standards of Ph.D.-granting universities. The rankings below will thus be of use to Geoscience departments interested in the overall pattern of publications at liberal arts colleges as they evaluate the research productivity of junior members of the department. Similarly, departments at liberal arts colleges might be interested in knowing how their research output compares to that of comparable schools. These comparisons might be important in thinking about a college's commitment of resources to research in geoscience. Research in science and geoscience can be expensive and colleges cannot expect to achieve substantial levels of publications without commensurate levels of spending. New Ph.D.'s on the job market might be interested in the research environment at liberal arts colleges in general or at particular colleges. And prospective college

students interested in majoring in geoscience might find these rankings of interest. Finally, the numbers presented here should be of use to new faculty members who, according to Boice (1992), often have unrealistic expectations of the level of research productivity expected at their institutions.

Of course teaching remains an important focus of liberal arts faculty. Given this, some might argue that ranking liberal arts colleges by research devalues the importance of teaching. However, McCaughey (1994) argues the contrary and demonstrates that there is a small positive correlation between scholarly activity and teaching effectiveness by professors at liberal arts colleges. Boice (1992) argues that the positive correlation between scholarly work and teaching effectiveness exists at colleges of all types. Teaching the latest discoveries in classes, supervising student theses and other research, and preparing students for graduate school are some of the teaching activities that may be enhanced by faculty research. Similarly, as Mogk (1993) has argued, it may be very important for students going on to graduate school in geoscience to have some form of research training. Faculty who are actively engaged in research themselves would seem to be best able to provide training of that sort. Previous research on economics and psychology has found a positive correlation between liberal arts faculty research output and the frequency with which their students obtain doctoral degrees (Hartley and Robinson, 1997; Schmauder et al., 1999).

DATA AND METHODOLOGY

We used the GeoRef database to compile a list of publications from 1970 to 1996 for which the first author's affiliation was one of the 161 schools classified as liberal arts colleges by the Carnegie Foundation (Carnegie Foundation for the Advancement of Teaching, 1987). Using the resulting list of articles we construct an overall ranking by the total number of journal articles and the number of abstracts for each institution. For this research we did not count maps, books, or reports. The author affiliations reported in GeoRef do not indicate departmental affiliation, so we counted all publications by authors who were at the college at the time the article was published (irrespective of their department). Thus the results represent of a measure of the research environment at a liberal arts college over time rather than a specific measure of the amount of research done by the current members of the Geoscience department. In the effort to determine if the pattern of publications has changed over time we present separate results for the period 1987 to 1996. We also present a table showing the total number of publications by all liberal arts faculty members in five year periods over the entire 1970 to 1996 period.

We collected geoscience department size information from Claudy (1997) or from the Department's Web page when necessary. From the National Resource Council (1996) we obtained data on the number of Ph.D.'s in geoscience granted between 1989 and 1994 to the graduates of each liberal arts college in our sample. We note that

the students earning their Ph.D.'s in the time range we surveyed are not necessarily the same students educated during the period when the published research was done. But because it was not possible to ascertain how many students are enrolled currently in Ph.D. programs, and because enrollment does not guarantee that a Ph.D. will be granted, we used the National Resource Council's data. We obtained National Center for Educational Statistics data on the number of geoscience graduates at each college from the Computer Aided Science Policy Analysis & Research Database System (Quantum Research Corporation, 1996).

Because our method measures only GeoRef catalogued publications whose first author listed a liberal arts college affiliation, our results should be interpreted as research listed in GeoRef, not the total research output of the geoscience department. Given the nature of liberal arts faculty, we would expect a fair amount of both interdisciplinary research (which might be published in a non-GeoRef journal) and writings for nonacademic publications, neither of which would be contained in our data set. Other factors besides the interest in research of a department of geoscience will also impact these rankings: for example, the age distribution of the faculty, the extent to which faculty from other departments engage in geoscience research, and the decision over which publications to list in GeoRef.

RESULTS

The rankings for the period 1970-1996 are listed in Table 1. Schools are ranked in four columns: 1) by the total number of journal articles; 2) by the total number of pages in journal articles; 3) by the total number of abstracts; and 4) by the number of journal articles per member of the department. There are a number of interesting patterns in Table 1. Publications at liberal arts colleges are highly concentrated among a few schools. The top 5 colleges are responsible for over 25 percent of the journal articles, while the top 20 colleges are responsible for two-thirds of the journal articles. Similar concentrations hold for pages and abstracts, where the top 5 colleges are responsible for 30 percent of the pages published and 25 percent of the abstracts. The relative concentration of publications among a few schools corresponds to McCaughey's (1994) argument that the shift in emphasis toward scholarly activity is more prominent at the top liberal arts colleges than in liberal arts colleges as a whole. Publication in geoscience, however, is more concentrated than in some of the social sciences. For example, in economics and psychology, the top 20 schools accounted for only around half of the articles published by faculty at liberal arts colleges (Hartley and Robinson, 1997; Schmauder, Hartley and Robinson, 1998). In part this may be due to the fact that many of the smaller colleges do not have geoscience departments. Comparing the columns for articles and abstracts shows that publishing in the form of journal articles is positively related to publishing abstracts. The correlation between number of articles and number of abstracts is over 0.92. Comparing

College	(1) Journal		(2) Total Pages		(3) Abstracts		(4) Dept. Size Ad- justed Articles	
	Rank	Articles	Rank	Pages	Rank	Abstracts	Rank	Articles
Franklin and Marshall College	1	91	3	1482	3	175	4	11.4
Colgate University	2	89	1	1799	1	258	9	9.9
Williams College	3	82	2	1579	5	137	3	13.7
Wesleyan University	4	66	4	1366	4	143	11	8.3
Middlebury College	5	53	8	968	2	200	5	10.6
Oberlin College	6	52	5	1324	12	96	1	17.3
Smith College	7	51	6	1011	6	126	13	7.3
Pomona College	8	42	15	563	23	67	6	10.5
Amherst College	9	41	7	1001	9	110	15	7.3
Colorado College	10	38	12	711	11	100	19	6.3
Lafayette College	10	38	9	795	8	114	10	9.5
Union College	12	37	17	535	24	65	21	6.2
Richard Stockton State College	13	33	11	720	14	94	2	16.5
Hamilton College	14	32	13	571	20	74	18	6.4
Vassar College	15	31	24	412	28	45	7	10.3
Bryn Mawr College	16	28	10	723	15	87	14	7
Hope College	17	27	27	308	36	37	16	6.8
Bucknell University	18	26	16	557	18	79	31	3.7
Allegheny College	19	25	21	439	39	29	20	6.3
Bates College	20	24	29	284	13	95	28	4
College of Wooster	20	24	14	563	7	118	22	6
Carleton College	22	22	18	483	10	107	34	3.2
Denison University	22	22	32	248	16	83	23	5.5
Furman University	22	22	20	446	22	68	26	4.4
Whittier College	22	22	40	182	41	24	12	7.3
Mount Holyoke College	26	21	22	434	17	82	32	3.5
Augustana College	27	20	44	151	40	26	17	6.7
Colby College	27	20	36	211	34	38	8	10
Macalester College	29	17	26	342	30	42	27	4.3
Dickinson College	30	15	33	226	30	42	30	3.8
Bowdoin College	31	14	23	416	34	38	37	2.8
Ohio Wesleyan University	31	14	38	193	45	17	24	4.7
St. Lawrence University	33	12	43	152	49	12	40	2.4
University of Puget Sound	33	12	30	280	36	37	35	3
Wellesley College	33	12	35	214	32	40	28	4
Eckerd College	36	11	45	129	47	16	*	*
Beloit College	37	10	25	356	21	70	38	2.5
Hampshire College	37	10	39	185	19	75	33	3.3
Knox College	37	10	53	72	57	7	*	*
Hobart and William Smith Col- leges	40	9	31	262	38	32	42	1.8
Occidental College	40	9	19	479	27	53	42	1.8
Albion College	42	8	42	154	32	40	46	1.6
Washington and Lee University	42	8	28	299	26	58	46	1.6
Hartwick College	44	7	34	223	29	44	44	1.8
Lawrence University	44	7	51	74	45	17	41	2.3
Earlham College	46	6	52	73	53	9	35	3
Whitman College	46	6	37	203	24	65	50	1.2
Alma College	48	5	49	78	54	8	24	5
Guilford College	48	5	54	66	43	23	49	1.3
Gustavus Adolphus College	48	5	46	115	41	24	45	1.7
Juniata College	48	5	48	80	58	5	38	2.5

* No Geology Department.

Table 1. Ranking of national liberal arts colleges by GeoRef published articles, pages, and abstracts 1970-1996, top 50 colleges.

Number of Publications				
Decade	Rank			
	Top 20	20-40	41 and lower	All
1990's	23.5	8.8	4.7	36.9
1980's	14.4	4.6	1.6	20.6
1970's	5.4	1.6	0.6	7.5
Percentage Increase Since the 1970's				
Decade	Rank			
	Top 20	20-40	41 and lower	All
1990's	337.3%	466.1%	653.4%	391.0%
1980's	167.7%	199.8%	155.6%	174.0%
Percentage Increase Since the 1980's				
Decade	Rank			
	Top 20	20-40	41 and lower	All
1990's	63.4%	88.8%	194.8%	79.2%

Table 2. Publications per year for the 1970's, 1980's, and 1990's by rank of institution.

the ranking indicates little difference between the rankings based on total articles and rankings based on pages.

There is little difference between the department size adjusted rankings and the overall article based rankings ($r=.94$). Because our measure of research is any article published by an author from the college our rankings are not specifically a ranking of departments at any one time and hence care should be used in interpreting the department size adjusted ranking. For example if the size of the department has changed over time or the amount of research done by non-department members is large, the department size adjusted rankings may be misleading.

Table 2 was constructed in order to determine if the amount of research has increased over time and shows the number of articles and abstracts published per year during the 1970's, 1980's and 1990's for all schools and for schools ranked 1-20, 21-40, and 41 and above. The results are striking. Overall productivity per year has increased by 391 percent for all schools between the 1970's and the 1990's and 79 percent between the 1980's and the 1990's. This seems to clearly bear out McCaughey's hypothesis. In addition the largest percentage increases have been at the schools with the lowest ranks. Schools ranked less than 40 saw an increase in publications per year of over 600 percent between the 1970's and 1990's and the growth rate for these schools between 1980 and 1990 was three times greater than the growth rate at the top twenty schools. Clearly their rate of publication remains substantially lower than for the most prolific schools, however it does appear that the changing ethos about research has expanded beyond the top schools.

Since we have seen that the research productivity of liberal arts faculties have increased considerably over time it is possible that the school rankings may have changed as well. To investigate this possibility Table 3 reports the same information as Table 1 for the ten years 1987 to 1996. Overall, the two rankings are quite similar. Twenty-one of the top 25 schools in terms of total articles in Table 1 are still in the top 25 in Table 3. There also appears to have been little change in the concentration of research activity of the top schools in recent years. The top five schools still are responsible for 25 percent of the articles published.

Since the data set contains information on every Geo-Ref listed journal article published by faculty at liberal arts colleges, we can explore issues related to what kind of research such faculty are doing. Table 4 lists the journals with the most geoscience articles published by liberal arts faculty between 1970 and 1996. Not surprisingly, the journal that published the most articles by liberal arts college faculty is the Journal of Geoscience Education, which published 94 articles written by liberal arts college faculty over this period. This is nearly as many articles as the second two leading journals combined and would appear to indicate that liberal arts college faculty combine their interest in teaching with their interest in publishing. We also note that this teaching interest coincides with high research productivity as 7 of the 10 most prolific colleges had articles in the Journal of Geoscience Education. Also interesting is the relatively high publication rate in Northeastern Geology which is possibly explained by the preponderance of liberal arts colleges in the Northeast.

Table 5 looks at the subject areas in which liberal arts college faculty published over the 1970 to 1996 period. In

College	(1)		(2)		(3)		(4)	
	Rank	Journal Articles	Rank	Total Pages	Rank	Abstracts	Rank	Dept. Size Adjusted Articles
Williams College	1	49	1	525	3	92	1	8.2
Colgate University	2	40	3	435	1	125	7	4.4
Wesleyan University	3	34	2	462	4	90	9	4.3
Union College	4	28	6	276	18	53	5	4.7
Franklin and Marshall College	4	28	7	269	2	111	15	3.5
Hamilton College	6	26	7	269	15	59	4	5.2
Colorado College	7	22	10	238	6	79	13	3.7
Smith College	7	22	5	282	5	83	18	3.1
Vassar College	9	19	13	172	28	37	2	6.3
Oberlin College	10	18	4	296	13	68	3	6.0
Pomona College	11	17	18	122	26	40	9	4.3
Lafayette College	12	16	9	256	9	75	11	4.0
Mount Holyoke College	13	15	11	205	15	59	20	2.5
Bryn Mawr College	14	14	14	151	15	59	15	3.5
College of Wooster	14	14	20	118	8	76	15	3.5
Augustana College	16	13	45	43	35	23	8	4.3
Amherst College	16	13	12	201	10	73	26	2.2
Denison University	18	12	37	54	19	51	19	3.0
St. Lawrence University	18	12	17	129	45	12	22	2.4
Carleton College	18	12	28	83	11	71	27	2.0
Bowdoin College	21	11	16	136	33	24	13	3.7
Bucknell University	21	11	19	119	21	48	33	1.6
Middlebury College	23	10	21	114	7	78	27	2.0
Richard Stockton State College	24	9	27	84	25	44	6	4.5
Dickinson College	24	9	23	97	33	24	24	2.3
Macalester College	24	9	15	149	29	31	24	2.3
Colby College	27	8	41	50	31	30	11	4.0
Eckerd College	28	7	28	83	45	12	*	*
Hampshire College	28	7	34	58	26	40	23	2.3
Occidental College	28	7	28	83	21	48	34	1.4
Washington and Lee University	28	7	22	107	23	47	34	1.4
Lawrence University	32	6	37	54	41	17	27	2.0
Ohio Wesleyan University	32	6	32	64	45	12	38	1.2
Wellesley College	32	6	35	56	29	31	27	2.8
Juniata College	35	5	42	49	57	3	20	2.5
Gustavus Adolphus College	35	5	33	59	39	21	32	1.7
Hope College	35	5	25	91	42	16	37	1.3
Albion College	35	5	44	47	37	22	39	1.0
Furman University	35	5	31	72	24	46	39	1.0
Bates College	35	5	40	51	12	69	45	0.8
Beloit College	41	4	39	52	14	64	39	1.0
Skidmore College	41	4	47	31	40	20	36	1.3
University of Puget Sound	41	4	26	89	35	23	39	1.0
Hobart and William Smith Colleges	41	4	24	93	37	22	46	0.8
Whitman College	41	4	53	21	20	49	46	0.8
Connecticut College	46	3	46	34	78	0	*	*
Cornell College	46	3	48	30	50	10	39	1.0
Whittier College	46	3	49	27	49	11	39	1.0
Allegheny College	46	3	42	49	44	13	48	0.8
Millsaps College	46	3	49	27	43	15	48	0.8

*No Geology Department.

Table 3. Ranking of national liberal arts colleges by GeoRef published articles, pages, and abstracts 1987-1996, top 50 colleges.

Journal	Articles	Pages
Journal of Geoscience Education	94	467
Geology	56	203
GSA Bulletin	48	546
Journal of Paleontology	47	568
Journal of Geology	32	415
Special Paper - Geological Society of America	31	444
Journal of Sedimentary Petrology	31	295
American Journal of Science	28	649
Geotimes	25	49
American Mineralogist	24	224
Initial Reports of the Deep Sea Drilling Project	24	521
Northeastern Geology	21	184
Antarctic Journal of the United States	21	50
Contributions to Mineralogy and Petrology	20	283
Canadian Journal of Earth Sciences	19	249

Table 4. Articles and pages published in geology journals by liberal arts faculty 1970-1996 (top 15 journals).

Journal	Articles
Igneous and metamorphic petrology	697
Structural geology	615
Stratigraphy	564
Quaternary geology	478
Paleontology	469
Sedimentary petrology	369
Geochemistry	269
Geomorphology	195
Hydrogeology	152
Environmental geology	138
Extraterrestrial geology and meteorites	135
Oceanography	121
Solid-earth geophysics	101
Economic geology	97
Mineralogy	86
Areal geology	81
Engineering geology	56
Applied geophysics	48
Soils	22
Seismology	20
General geophysics	7

Table 5. Subject of geological research by liberal arts college faculty, 1970-1996.

part the pattern of research is likely driven by relatively small size of the departments at liberal arts colleges. The average geoscience department in our sample had four faculty members. It is quite likely that these four faculty would be in the fields of igneous and metamorphic petrology, structural geology, stratigraphy, and quaternary geology which are the fields in which the largest amount of research done by liberal arts college faculty.

RESEARCH AND TEACHING

The geoscience research done at national liberal arts colleges, while valuable in and of itself, would be more valuable if, as McCaughey argues, it is connected to the teaching effectiveness of the college or as Mogk (1993) argues it prepares students for graduate school. Measures of teaching effectiveness are hard to compute. However, one readily available measure of teaching quality is the number of students from a liberal arts college who go on to graduate work. McCaughey (1994, 94) discusses the educational research that "links certain kinds of academic environments with one kind of good teaching, 'mentoring,' teaching that encourages students to aspire to the professional study of the subject and eventually to teach it." This might imply that there is a relationship between the research done by faculty and the achievements of their students at graduate school.

In order to test the hypothesis that research and mentoring might lead more students to go on to professional study we examined the relationship between faculty research measured by the number of articles published and the number of undergraduates completing Ph.D.'s. Data were collected on the number of Ph.D.'s in geoscience granted between 1989 and 1994 to the gradu-

Rank Cohort	Number of Ph.D.'s in Geology	Percent of Total Ph.D.'s from Liberal Arts Colleges
1-20	354	45.4
21-40	186	23.8
41-60	96	12.3
61-80	59	7.6
81-100	8	1.0
101-120	13	1.7
121-140	31	4.0

Table 6. Distribution of Ph.D.'s granted from liberal arts colleges (1989-1994) across rank cohorts (1970-1996).

ates of the liberal arts colleges in our sample. Table 6 shows the relationship between college rank from Table 1 and number of Ph.D.'s received by the graduates of the college. Nearly half (47.5 percent) of the Ph.D.'s in geoscience received by liberal arts college graduates come from the schools ranked in the top 20 by publications in GeoRef journals. We also estimated a linear regression of the number of Ph.D.'s received by the graduates of a liberal arts college on the total number of journal articles published by the faculty of that college between 1987 and 1996. We controlled for number of undergraduates receiving geoscience degrees at the college (assuming bigger departments with more majors should send a larger number of students to graduate school) and the quality of the institution as measured by the 1995 US News & World Report ranking (assuming more highly rated colleges will attract better students more capable of graduate work).

The results of the regression are as follows:

$$\text{Ph.D.'s} = 5.19 + 0.14(\text{Articles}) + 0.10(\text{Grads}) - 0.04(\text{USNews Rank})$$

(5.64) (2.28) (9.67) (-4.92)

R-squared = 0.69, N = 160,
(t statistics in parentheses)

The number of journal articles published by the faculty is significantly positively related to the number of students going on to get Ph.D.'s in geoscience even after controlling for number of geoscience majors and overall college quality. This indicates that both McCaughey and Mogk were correct to connect the graduate school accomplishments of students to the research output of the faculty. This result also confirms that at least one measure of teaching effectiveness is connected to research and thus that there is at least some teaching information contained in publication-based rankings. Moreover, it confirms Mogk's (1993) underlying assumption that providing students with exposure to research will increase their willingness and capability to attend a graduate program in geoscience. Clearly, further research on the connections between teaching and research would be valuable. It might be particularly useful to examine the relationship between faculty research and student research either as co-authors or in informal student outlets.

CONCLUSION

This paper has presented rankings of national liberal arts colleges based on publications in GeoRef listed journals. We find evidence that this research is highly concentrated among a relatively few colleges and has increased substantially over time. The rate of increase has been the greatest at the schools with fewer total publications indicating that the emphasis on research has spread to more colleges. We also find evidence that geoscience faculty are deeply interested in teaching, as evidenced by publications in the *Journal of Geoscience Education*. Finally we find that faculty research appears to contribute to successful teaching, as measured by the number of undergraduates who go on to obtain Ph.D.'s in Geoscience.

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