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PUBLICATION PRODUCTIVITY IN DOCTORAL RESEARCH DEPARTMENTS: Interdisciplinary and Intradisciplinary Factors

Leonard L. Baird

Examination of a national data set reporting departmental levels of publication productivity in 23 disciplines revealed very large differences between disciplines, with the mean departments in the most "productive" disciplines averaging more than 10 times the number of publications of the mean departments in the least "productive" disciplines. The differences within disciplines were also very large. Analyses of the characteristics of departments associated with productivity showed great variation across disciplines. Regression analyses indicated the importance of size and internal university support rather than federal support. Similar results are reported for the number of citations to the work of departments. The implications of these results for program review and the reputations of departments are reviewed.

The factors in departmental research productivity are of both theoretical and pragmatic interest. The research interest is in the identification of the mix of people and resources that leads to high departmental levels of contributions to disciplines. The practical interest is in capitalizing on that research to help one's own department become more productive. The research that bears on this question (e.g., Blackburn, Behymer, and Hall, 1988; Fox, 1985; Braxton, 1986) has been intriguing but more suggestive than based on empirical work. The study by Baird (1986) deals with the question fairly directly, but is based on only three disciplines. All of this research suggests, however, that the answers to the question will vary across disciplines, and that research productivity may be much more influenced by financial and human resources than the subtleties of group interaction.

The current study used a broader data set, the *Assessment of Research-Doctorate Programs in the United States* (Jones, Lindsey, and Coggeshell, 1982), to attempt to address these questions. This data set has the advantage of includ-

Leonard L. Baird, Educational Policy Studies, University of Kentucky, 145 Taylor Building, Lexington, KY 40506–0001.

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ing information about most arts and science and engineering disciplines, and is based on virtually all doctoral-granting institutions within disciplines. Thus, it is a very useful data set for conducting analyses comparing disciplines. The data include a measure of the total number of articles produced by each program (except for the humanities) and a measure of the average "influence" of the articles in the disciplines (except for the humanities and social sciences). The data also include measures of variables that may affect productivity, as well as measures suggestive of the outcomes of the programs for students.

METHOD

The data come from the study sponsored by the Conference Board of Associated Research Councils, including the American Council of Learned Societies, American Council on Education, National Research Council, and Social Science Research Council. The data were based on surveys sent to each institution, the National Research Council's Survey of Earned Doctorates, reputational surveys of faculty, data from the Association of Research Libraries, and publication information compiled by the Institute for Scientific Information. The survey and data compilation methods are described in detail in Jones, Lindsey, and Coggeshell (1982). The data were compiled for research-doctorate programs in 32 disciplines from 228 universities. The variables studied included the following.

Available for All Disciplines

Program Size (Based on Surveys of Institutions)

1. Reported number of faculty members in the program, December 1980.
2. Reported number of program graduates in the last 5 years (July 1975 through June 1980).
3. Reported total number of full-time and part-time graduate students enrolled in the program who intend to earn doctorates, December 1980.

Characteristics of Graduates (Based on NRC's Survey of Earned Doctorates)

4. Fractions of FY 1975–79 program graduates who had received some national fellowship or training grant support during their graduate education.
5. Median number of years from first enrollment in graduate school to receipt of the doctorate—FY 1975–79 program graduates.
6. Fraction of FY 1975–79 program graduates who at the time they completed requirements for the doctorate reported that they had made definite commitments for postgraduate employment.
7. Fraction of FY 1975–79 program graduates who at the time they completed requirements for the doctorate reported that they had made definite

commitments for postgraduation employment in Ph.D.-granting universities.

Reputational Survey Results (Based on Surveys of Faculty, Questions Virtually Identical to Those Used by Roose and Anderson [1970])

8. Mean rating of the scholarly quality of program faculty.
9. Mean rating of the effectiveness of the program in educating research scholar/scientists.
10. Mean rating of the improvement in program quality in the last 5 years.
11. Mean rating of the evaluators' familiarity with the work of the program's faculty.

University Library Size (Based on Data from the Association of Research Libraries)

12. Composite index describing the library size in the university in which the program is located, 1979–80.

Available for All Disciplines Except Humanities

Research Support (Based on Institutional Surveys)

13. Fraction of program faculty members holding research grants from the National Science Foundation, National Institutes of Health, or the Alcohol, Drug Abuse, and Mental Health Administration at any time during FY 1975–79.
14. Total expenditures (in thousands of dollars) reported by the university for research and development activities in a specific field, FY 1979.

Publication Record (Based on Data from the Institute for Scientific Information)

15. Number of published articles attributed to the program 1978–79 (in the case of Social Sciences, 1978–80).

Available for Engineering, Biological Sciences, and Mathematical and Physical Sciences

16. Estimated "overall influence" of published articles attributed to the program, 1978–79, based on weightings of journals according to the citation rate.

These measures were tabulated and standardized for programs in disciplines in five areas: Biological Sciences, Engineering, Humanities, Mathematical and Physical Sciences, and Social and Behavioral Sciences. The unstandardized and standardized data for each department in each discipline are presented in Jones, Lindsey, and Coggeshell (1982), along with a correlation table of the intercorrelations of the variables for each discipline. Extensive details about each of these measures are provided in the Jones work.

It should be noted that there is a considerable degree of collinearity in the matrices in many disciplines. For example, and for obvious reasons, the correlations among the three size measures tend to be high; the correlations among the reputational ratings also tend to be high; and the correlations between university expenditures in the discipline were indirectly correlated with library size.

STATISTICAL TREATMENT

Using the discipline as the unit of analysis, the mean and range of publications as well as the correlations were tabulated, using techniques of exploratory data analysis (Hoaglin, Mosteller, and Tukey, 1983). These methods provided information about the median correlation and also explored systematic differences among the correlation among the disciplines. In addition, regression analyses were conducted for each discipline, using publications and citations as dependent variables.

RESULTS

Since publication data are available for all disciplines except the humanities, but citation rate is not available for either the humanities or the social sciences, they will be discussed separately.

Publications

The average number of publications for each department in each discipline, along with the range of departments from the tenth percentile to the ninetieth percentile, are shown in Table 1. The ratio of the production of the most productive tenths to the least productive is also shown. For example, in Biochemistry, the department in the most productive tenth produced 17 times as many articles as those in the least productive tenth. The disciplines with the highest averages were Cellular and Molecular Biology, Physics, Biochemistry, Psychology, and Chemistry. The disciplines with the lowest averages were Chemical Engineering, Mechanical Engineering, Civil Engineering, Statistics, and Zoology. With the exception of the Engineering area, there were large

TABLE 1. Variation in Publishing Patterns Within Disciplines

Discipline	Mean	Lowest Tenth	Highest Tenth	Range Low–High	Ratio High/Low
Biochemistry	92	13	224	211	17.2
Botany	60	11	131	120	11.9
Cellular/Mol Biology	133	15	325	310	21.7
Microbiology	46	7	100	93	14.3
Physiology	17	2	39	37	19.5
Zoology	16	5	29	24	5.8
Chemical Engineering	10	1	22	21	22.0
Civil Engineering	12	1	27	26	27.0
Electrical Engineering	22	4	50	46	12.5
Mechanical Engineering	11	2	22	20	11.0
Chemistry	78	19	161	142	8.5
Computer Science	34	10	65	55	6.5
Geosciences	44	9	102	93	11.3
Mathematics	39	10	76	66	7.6
Physics	106	19	269	250	14.2
Statistics	12	2	30	28	15.0
Anthropology	30	9	54	45	6.0
Economics	52	13	112	99	8.6
Geography	17	4	30	26	7.5
History	43	10	82	72	8.2
Political Science	43	14	77	63	5.5
Psychology	81	17	165	148	9.7
Sociology	52	16	90	74	5.6

differences among disciplines within areas as well. The Biological Sciences include Cellular and Molecular Biology, and Biochemistry, disciplines with very high means, and Zoology and Physiology, disciplines with low means. The Mathematical and Physical Sciences include Physics and Chemistry, two high-mean disciplines, and Statistics, a low-mean discipline. The Social and Behavioral Sciences include Psychology, a high-mean discipline, and Geography, a low-mean discipline.

The disciplines also varied in the range of productivity. In terms of ratios of most to least productive programs, high-variation disciplines included Civil Engineering, Chemical Engineering, Cellular and Molecular Biology, Physiology, and Biochemistry. The low-variation disciplines include Political Science, Sociology, Zoology, Anthropology, and Computer Science. Thus, there are large differences in the meaning of productivity across disciplines. The highest discipline averaged 133 publications per program; the lowest discipline averaged 10.

TABLE 2. Distributions of Disciplinary Correlations of Number of Program Publications with Other Variables

	Number of Faculty	Number of Graduates	Number of Students	% Students National Fellowship	Average Years to Doctorate
96–100					
91–95					
86–90	S		M		
81–85	E S	E M M M M S	M		
76–80	S S S	S	E M		
71–75	E M M	E M	M S		
66–70	M S	E E S B	M		
61–65	E M M B	S	E		
56–60	S	B	E E B		
51–55	B B	M	M M S		
46–50	M	S S S	M S S	B	
41–45	E B	B	S	B	
36–40	M B			S	M M M S
31–35	B (Zool)	B (cell/m)	S S B B B	B S S S S	S
26–30			B	B	M M B E
21–25		B (botany)		B S	E S
16–20		B (psych)		B	B
11–15			B (psych)	S	S B
06–10				M M	E S S
00–05				M M	B B E
					−04 S
				−03 M (Chem)	−07 M (Comp Sci)
				−32 M (Stat)	−15 B (Physiology)

	Percent of Graduate Commitments Employment	Percent of Graduate Commitments Ph.D. University	Ratings of Faculty	Ratings of Program Effectiveness	Ratings of Improvement
96–100					
91–95					
86–90					
81–85			B M	M S	
76–80			E M S S S S	B E M S S	
71–75			B M M S S S	E M M S S S	
66–70			B B E M M	B M M S	
61–65			E E	B B B E E	
56–60			B B	E	
51–55					
46–50		S S M			
41–45	M	S S			S
36–40	S	S S M			E S
31–35	S	S M B B B			E M B
26–30	B S S	M B B			S B B
21–25	M B B S	E B			E S B
16–20	E E				E M S S B
11–15	M E	E M			M S B
06–10	M B B E S S	E			M
00–05	M M	E			M
		−08 M (Comp Sc)			−13 M (Physics)

	Rater Familiarity	Library Size	% Faculty Federal Research Grants	Univ. Funds Res. in Discipline	"Influence" or Citations to Publications
96–100					B B B B E E M M M M
91–95					B E M
86–90					B E M
81–85	E M M B				
76–80	S S S B			M (Physics)	
71–75	E M M S S S	S		B B	
66–70	E M M S B	B M S S S		M M	
61–65	E B B	B M S		E	
56–60		B M	S	B S	
51–55	B	M S	S M	S S	
46–50		B E M S	B B M M E	B E	
41–45			S S M	B B S M E	
36–40		B E	B B S	E	
31–35		B E M	B M E E	M (Math)	
26–30			S E		
21–25					
16–20			M		
11–15		E			
06–10					
00–05					
			−02B (Botany)		

Note: See text for explanation.

As noted there are also large differences among programs within disciplines. In half the disciplines the most productive tenth was at least 10 times as productive as the least productive tenth. Even in the least-variable disciplines the highest tenth was more than 5 times as productive as the lowest tenth. These differences are not explained simply by size of department. The largest 10 percent of departments are only about three to four times as large as the smallest 10 percent in almost all disciplines.

As shown in Table 2, the median correlation across disciplines between number of publications and the other measures varies. In this table B = Biological Sciences (Biochemistry, Botany, Cellular and Mollecular Biology, Microbiology, Physiology, Zoology), E = Engineering (Chemical Engineering, Civil Engineering, Electrical Engineering, Mechanical Engineering), M = Mathematical and Physical Sciences (Chemistry, Computer Science, Geoscience, Mathematics, Physics, Statistics/Biostatistics), and S = Social and Behavioral Sciences (Anthropology, Economics, Geography, History, Political Science, Psychology, Sociology). The first S on Number of Faculty, for example, shows that a Social or Behavioral Science, in this case History, had a correlation between .86 and .90 with number of publications. The size had median correlations with number of faculty .63, number of graduates .68, and number of students .52. Thus, enrollment is less significant than number of graduates. The major discipline difference was between the Mathematical and Physical Sciences where, for example, the median correlation with number of graduates was .82, and the Biological Sciences where the median correlation was .38.

In the area of characteristics of graduates, the median correlation between publications and fraction of graduates with a national fellowship or training grant was only .12, but for the Biological Sciences the median was .48, for Mathematical and Physical Sciences .02, and for Engineering .00. The median correlation of publications and years to doctorate was .17, as was the correlation with commitments for employment, with no clear trends among disciplines. The median correlation between publications and commitments from Ph.D. universities was .33 across all disciplines. However, the median for the Engineering disciplines was .12 and for the Social Sciences .42.

The median correlations between publications and ratings of scholarly quality of faculty, effectiveness of program, and respondents' familiarity with the program were all .73; and the correlation between publications and program "improvement" was .21. There were no clear interdisciplinary differences.

The median correlation between publications and library size was .52, although the median for the engineering disciplines was .35, in contrast with that for the Social Sciences, .68. The median correlation of publications with fraction of faculty with a federal research grant was .41 and with research expenditures .47, with no clear interdisciplinary differences.

As shown in Table 3, the disciplines also varied in the degree to which productivity was predictable from departmental characteristics; R^2 values varied from .18 to .84. The most "predictable" disciplines were History (.84), Electrical Engineering (.81), Biochemistry (.75), Chemistry (.75), and Economics (.75). The least "predictable" were Chemical Engineering (.18), Botany (.26), Physiology (.26), Geography (.35), and Zoology (.37). The most commonly appearing variable in the equations was number of graduates, followed by university funds for research in the discipline, number of students, number of faculty, and size of library. Interestingly, the percentage of faculty with federal grants was a predictor in only one discipline. All of this suggests that research productivity is dependent on program size and internal resources. There are no obvious patterns that would explain the results. For example, it is quite unclear as to why productivity in Chemical Engineering is not predictable from departmental characteristics, whereas productivity in Electrical Engineering is quite predictable; or why productivity in Physiology is poorly predicted from departmental characteristics, whereas productivity in Biochemistry is predicted fairly well.

TABLE 3. Summary of Regression Analyses with Program Publications as Dependent Variables

	Biochemistry	Botany	Cell/Mol Biol	Microbiology	Physiology	Zoology	Chemical Eng	Civil Eng	Electrical Eng	Mechanical Eng	Chemistry	Computer Sci	Geoscience	Mathematics	Physics	Statistics	Anthropology	Economics	Geography	History	Political Sci	Psychology	Sociology
1. Number of Faculty	.26					.79		.43	.38			.50		.47				.50		.51	.40		
2. Number of Graduates	.29	.19	.17			−.28		.38	.35	.37	.48	.17	.41				.69	.41	.26	.26			
3. Number of Students			.17	.23			.42							.50	.40	.36			.16			.23	.19
4. Grads with Natl Fell								.18								.32							
5. Years to Doctorate					−.16												.07						.30
6. % Grads Employment										.13													
7. % Grads PhD Univ					.28																		
8. Rating Faculty															.37						.22		
9. Rating Program																				.15		.54	
10. Rating Improvmt	.15					.17											.27						
11. Rater Familiarity									.24	.46	.42									.17			
12. Library Size											−.15		.27			.26				−.10	.21	.15	.50
13. Faculty with Fed Grants																.31							
14. Univ Support of Research	.49	.45	.57	.71	.34			−03			.12		.15					.08			.19	.17	.23
R^2	.75	.26	.44	.59	.26	.37	.18	.62	.81	.61	.75	.40	.76	.72	.52	.51	.59	.75	.35	.84	.73	.62	.65

"Influence" or Weighted Citation to Articles

Since citations are only reported in standardized forms based on the average for each discipline, the mean and variation are the same for every discipline, and therefore are not shown. The results for the correlations of influence of the program's articles were very similar to those for publications (not surprising, since the median correlation between the two variables was .96). The distributions of correlations are shown in Table 4. The median correlation between the "Influence" of articles and each of the variables as numbered in the methods section were (1) .56, (2) .63, (3) .52, (4) .10, (5) .17, (6) .18, (7) .28, (8) .73, (9) .68, (10) .20, (11) .71, (12) .53, (13) .43, (14) .56, and (15) .96. The patterns of interdisciplinary differences were very similar, except that "Influence" was more highly related to the fraction of faculty with federal grants in the Mathematical and Physical Sciences (median .71) than in the Engineering disciplines (median .37).

The regression results shown in Table 5, were highly similar to those reported for publication rates and are not discussed further.

DISCUSSION

There are large differences in the meaning of productivity across disciplines, a result consistent with much earlier research. A program with 15 publications would be highly productive in Chemical Engineering, but would be far below average in Biochemistry. These differences are probably due to the traditions and methodologies of the disciplines. Obviously, any judgments about the productivity of a program must be made based on the norms of the program's discipline. This point is as important for administrative decisions as for research studies. Budgetary or policy decisions need to be made within the context of the discipline. As suggested by Table 1, even judgments within an area, such as the Biological Sciences, should not be made across disciplines, but by comparisons with other programs within each discipline.

Of more theoretical interest are the differences within disciplines. Disciplines differ in the variability of publication rates by programs, a result that leads to intriguing questions. For example, why do programs in Cellular and Molecular Biology vary so much in productivity compared to Zoology, another Biological Science? Why is Physics twice as variable as Mathematics, two disciplines that are often thought of as highly interrelated? As we have seen, these differences are not explainable simply by size of department, nor do they seem to be due to dependence on equipment or resources, which might increase differences among programs. For example, Computer Science, a discipline obviously needing technological support, has relatively low variability. A more likely explanation is the difference in program emphases on research and the reward structures

TABLE 4. Distributions of Disciplinary Correlations of "Influence" of Program Publications and Other Variables

	Number of Faculty	Number of Graduates	Number of Students	% Students National Fellowship	Average Years to Doctorate	% Grads Commitment Employment	% Grads Commitment PhD Univ	Ratings Faculty Quality
96–100								
91–95								
86–90		M M						M M
81–85	E	E M M	E M M					B M
76–80			M					E M M
71–75	M	M						B B B
66–70	E	E						M
61–65	M M M	B E	M					B B E
56–60	B E	B	E	B				E E
51–55	B B	E	B E M	B				
46–50	E M	M	M	B			M	
41–45			E	B	M	M	B	
36–40	B B M M				M M M		M	
31–35		B	B B B		M		B B B	
26–30		B			B E	B B	B B M	
21–25		B				B E M	M	
16–20		B	B	B E M	B B	B E M M	E	
11–15			B	M	B E	B B M	E E	
06–10				E M	E	E E		
00–05				E E M M		M	E	
				−11B (Bot)	−03B (Mic)		−01M (ComSc)	
				−29M (Stat)	−04 (ComSc)			
					−05E (Civil)			
					−42b (Phys)			

Note: See text for explanation.

TABLE 4. (Continued)

	Rating of Program Effectiveness	Ratings of Program Improvement	Rater Familiarity	Library Size	% Faculty Fed Res Grants	Univ Funds Res in Discipline
96–100						
91–95						
86–90			M M			
81–85	M M		B B E M			
76–80	B E M					B M M
71–75	M M		B M			B M
66–70	B B		B E M M	B M		
61–65	B B B E E M		B	M		E
56–60	E		B E E	B M M	M M	B
51–55				B E M	B E M M	B
46–50				B	B B	B B
41–45						E M
36–40				B B E M	B B	
31–35		E E M		E	E M	E E M
26–30		B B			E	
21–25		B B E			M	
16–20		B B E			E	
11–15		M		E		
06–10		M				
00–05		M M			B (Bot)	
		−14M (Phys)				

TABLE 5. Summary of Regression Analyses with "Influence" of Publications as Dependent Variables

	Biochemistry	Botany	Cell/Mol Biol	Microbiology	Physiology	Zoology	Chemical Eng	Civil Eng	Electrical Eng	Mechanical Eng	Chemistry	Computer Sci	Geoscience	Mathematics	Physics	Statistics
1. Number of Faculty	.21	.44		.23	.59		.34	.34	.38	.18				.67		.40
2. Number of Graduates								.30	.38		.18				.40	
3. Number of Students	.24					.34										
4. Grads with Natl Fell				.22												
5. Years to Doctorate			.21										.34			.25
6. % Grads Employment																
7. % Grads PhD Univ													.24			
8. Rating Faculty																
9. Rating Program																
10. Rating Improvmt	.11													−.20		
11. Rater Familiarity							.33			.35	.39					
12. Library Size							.24					.38				
13. Faculty with Fed Grants									.24							
14. Univ Support of Research	.57	.36	.50	.62					.14		.20	.61	.27	.28	.39	
R^2	.70	.46	.52	.69	.29	.12	.58	.51	.85	.43	.85	.71	.34	.53	.84	.37

within departments. These variables are, of course, beyond the scope of the present study, but deserve investigation.

Perhaps the strongest result in these findings is that publications and "Influence" are related to the reputation of the faculty, ratings of the effectiveness of the program, and the familiarity of the raters with the program. Although the data are not organized for causal analyses, it seems clear that the ratings are the result of publications and the influence of articles rather than the reverse. A reasonable model would be that publications lead to raters' familiarity with the program faculty, which leads to judgments about faculty quality, which in turn influences judgments about program effectiveness (Saunier, 1985).

However, this chain of events is a consequence of departmental publications. What leads to publications? Size of program is an obvious factor, since, on the average, the more faculty in a department, the more publications it will produce. However, an intriguing finding is that *number of graduates* is even more highly related to publications and influence than number of faculty. This may be due to the involvement of students in large research projects, as suggested by Baird (1986). Thus professors would use a part of the project for publications with their students, which would also lead to student dissertations.

More direct measures of "resources" are also related: Fraction of faculty with federal research grants, university expenditures for research in the discipline, and library size are all related to both criteria. Success in obtaining grants, university commitments to the discipline, and current scientific and scholarly information would clearly tend to promote high levels of productivity and "influence." However, another "human resource" is not related: the fraction of graduates who had received some national fellowship support. One might expect that the presence of large numbers of able students would increase productivity. However, if we take this variable as one of the consequences of the program's research productivity for students, it is part of an overall pattern of relatively small relationships.

Publications and "Influence" are also only minimally related to the efficiency of the program in producing Ph.D.'s (time to doctorate) and to graduates' prospects for employment. The moderate correlations of publications and influence with graduates' reports of job commitments from Ph.D.-granting institutions are probably due to their influence on the judgments of faculty in other institutions about the quality of the program, which is then transferred to the student when he or she applies for a position. Thus, although the variables in this study are rather different than those used in Baird (1986), the analyses are consistent with that research: The publications rate of departments has little to do with educational outcomes for students.

The most interesting result was that both among the zero-order correlations and in the regression analyses, university funding for research in the discipline was a better predictor than was the level of federal funding of both publications and citations.

Some reflection on the nature of federal contracts makes this result understandable. Many contracts are awarded on the basis of responses to RFP's, which spell out the topic to be investigated, and often make strong suggestions about the methodology and models to be used. In addition, the projects are often highly pragmatic, designed to find the answer to some federal policy question rather than to basic theoretical questions in the disciplines. Finally, most of the project activities involve the operations of conducting the research and preparing reports to the awarding agency. There is often no funding or faculty energy left to write publications for journals. All of these factors mitigate against federal research projects leading to publications, especially publications dealing with basic or theoretical questions in the discipline, which are the ones most often cited. In contrast, university funds to a discipline usually have relatively few restrictions, and there may be much more emphasis on the theoretical and basic research. In addition, the funds can be focused directly on research that has a high probability of resulting in publications, rather than on activities that have publications as a side product, as is the case with most federal projects.

All of this calls into question the current headlong pursuit of federal funding by universities. Although such funding may help balance the university's budget, it will not necessarily lead to publications, or, as suggested by the model outlined above, to a higher reputation for the department or institution. The university monies spent on the chase for federal dollars might be better spent in funding small faculty projects that have the potential for contributions to the literature.

This study also reveals some patterns that distinguish among disciplinary areas. In the analyses, the Engineering disciplines were often unlike most other disciplines, especially in that various measures of resources were relatively unimportant to productivity and influence, perhaps because professors may use contracts with industry to support their research. An interesting contrast is between the Mathematical and Physical Sciences, where numbers of graduates and students were relatively important and fraction of students with some national fellowship was relatively unimportant, and the Biological Sciences, where numbers of graduates and students were relatively unimportant and fraction of students with national fellowships was relatively important. In addition, specific disciplines (e.g., Computer Science, Psychology, and Music) had results that set them apart from other disciplines in their areas. Further analyses are being conducted to help explicate these results.

In summary, consistent with Saunier (1985), although there are some disciplinary differences, it appears that program size and resources lead to publications and "Influence," which in turn lead to the scholarly reputation of the program. Consistent with Baird (1986), there are relatively few consequences for students.

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