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Teaching and Research in Engineering Education*

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The National Science Foundation has recently attempted to revitalize undergraduate engineering education in the United States by funding efforts to encourage more faculty involvement in teaching. This approach assumes that time spent on teaching and instruction plays an important role in faculty reward structures. This paper examines the assumption that teaching is a highly valued activity in faculty reward structures by analyzing data from a national survey of faculty. Results show that research and scholarship, not teaching, are the strongest predictors of compensation, and that time spent on teaching can be negatively related to compensation.

TEACHING VERSUS RESEARCH

SINCE 1985, the National Research Council has raised concern about the quality of undergraduate education in the United States. Of particular concern has been the retention rate of engineering majors, the potential shortage of engineers and the content of the engineering curricula, particularly the lack of design [1–4]. In 1990, the National Science Foundation (NSF) undertook a major effort to fund two consortia of American universities whose principal goal was to revitalize undergraduate engineering education. These consortia have focused on incorporating more design activities into courses, encouraging more active student involvement in their own education and emphasizing new instructional techniques for faculty [5].

The assumption made by NSF in funding these consortia was that external support was needed to enhance the status of teaching and instruction, and thereby to transform undergraduate engineering curricula. This assumption rested on the belief that teaching is a positive or at least neutral component of faculty reward structures. The NSF effort also assumed that external impetus could change the value placed by academic institutions and their faculty on teaching and instruction.

What role does teaching play in faculty reward structures? Using compensation as the criterion because it is an annual 'reward,' reflecting at least in part the value placed by the institution or department on the work of individual faculty, the evidence has been ambiguous. Kasten's [6] review of the literature documented that teaching has been found to be positively related to salary and promotion [7–11], unrelated to salary and promotion [12, 13] and negatively related to salary and promotion [14]. In contrast, faculty research activity was consistently, positively related to promotion and salary [8, 9, 11–13, 15, 16].

This article examines the relationships between faculty activities—teaching and instruction, research and scholarship, administration, public service—and compensation to highlight the implicit emphasis on various faculty behaviors given by academic institutions through compensation. Three competing perspectives were examined: (a) teaching is a *positive* factor in compensation (i.e. faculty who spend more time teaching and whose teaching productivity is high are paid the most), (b) teaching is a *neutral* factor in compensation (i.e. teaching is not a significant predictor of compensation) and (c) teaching is a *negative* factor in compensation (i.e. people who spend more time teaching get paid less).

THE STUDY

Data for this research were gathered from the 1987–88 National Survey of Postsecondary Faculty, sponsored by the National Center for Education Statistics in the United States Department of Education. The survey examined a nationally representative sample of 11,071 faculty from 480 colleges and universities; 8,383 full- and part-time faculty from 424 institutions responded, a faculty response rate of 76%. The institutional sample was stratified by type of institution [17], source of control and size (estimated number of faculty). Institutional types included research universities, whose faculty train the majority of doctorates in the United States and which house the majority of funded research, doctoral-granting

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universities, whose faculty also train doctoral students and conduct research but at a lower level than their counterparts in research universities, comprehensive colleges and universities, which focus on liberal arts and professional programs at the undergraduate and masters-degree levels, liberal arts colleges, other four-year institutions, which in this study were predominantly professional schools of engineering and medicine, and two-year colleges. Eligible sample members were faculty who had some instructional duties during the Fall term, 1987 [18, p. 97].

The focus of this report is on *full-time*, *tenure-track* faculty from four-year institutions (n = 4,481, weighted n = 343,343). The range of institutional types includes research universities, doctoral-granting institutions, comprehensive colleges and universities, liberal arts colleges and other four-year institutions.

STUDY VARIABLES

Compensation

The measure of compensation used in this research was *basic salary from the institution*: 'For the calendar year 1987, what were your gross earnings before taxes for your basic salary at this institution?'

Demographic characteristics

Faculty demographic characteristics examined in this study were *age* (during Fall term, 1987), *gender*, *ethnic/racial minority status*, *highest degree awarded* (doctorate or lower) and *program area*. A respondent was classified as a member of a racial or ethnic minority if she or he was (a) Caucasian and of Hispanic descent, (b) American Indian, (c) Asian/Pacific Islander or (d) Black. Program area was the primary field of study in which a faculty member worked: agriculture/home economics, business, education, engineering, fine arts, health sciences, humanities, natural sciences, social sciences and other fields.

Length of service

Length of service was measured by *time in current rank* (i.e. the number of years since achieving the rank held at the institution in question during Fall term, 1987) and the *number of years in the current position* at the institution in question (irrespective of changes in rank).

Teaching/instruction

Faculty instruction-related activities consisted of measures of how faculty spent their time, workload and productivity. These are *not* measures of instructional quality.

Nevertheless, these generic measures of productivity provide insights into how faculty are rewarded for their efforts.

Three measures of instruction-related activities and workloads were used: *percentage of time spent on teaching and instruction*, *hours spent in the classroom per week*, and the *type of student taught* (undergraduate, graduate or both). The percentage of time spent on teaching and instruction included time spent on working with student organizations, teaching, advising and supervising students, and grading papers, preparing courses and developing new curricula.

Total student contact hours generated during Fall term, 1987 was used as a measure of instructional productivity. Student contact hours were estimated by the sum across all courses taught of the number of hours a class met per week times the number of students enrolled in the class.

Research/scholarship

Research and scholarship was examined by one measure of faculty activity—*percentage of time spent on research and scholarship*—and two measures of productivity—*total refereed publications during the career* and whether or not the respondent was a *principal investigator* (or co-principal investigator) on an externally-funded research project during Fall term, 1987. The percentage of time spent on research and scholarship included time spent on research, scholarship, preparing or reviewing articles or books and attending or preparing to attend professional meetings or conferences, giving performances in the fine or applied arts and seeking outside funding for research. Total refereed publications for the career included the total number of refereed articles, chapters in edited volumes, textbooks, other books, monographs, and reviews of books, articles or creative works. Being designated as a principal investigator or co-principal investigator meant having at least one research project during Fall term, 1987, funded by the federal government, state or local governments, foundations or other non-profit organizations or industry. Individuals whose sole support for research was an institutional grant were *not* considered to be principal investigators by this standard.

Administration and public/community service

To fill out the picture of the faculty workload, estimates of the *percentage of time spent on administrative activities* and *time spent on public or community service* were also included.

Scales

High positive correlations between age, time in rank and years at current institution (0.65–0.69), and a high negative correlation between the percentage of time spent on teaching and research (−0.62), suggested the need to create composites prior to proceeding with multivariate analyses. A principal components analysis with an oblique rotation was used to create two composites. The first was 'seniority,' which combined age, time in rank and years at the current institution into a single scale. The second was derived from the finding that time spent on research and on teaching are inseparable—the more

faculty spend on one activity, the less they spend on the other. The second composite—'more research/less teaching'—reflected this 'exchange' relationship.

ANALYSES AND PRESENTATION OF RESULTS

Using weighted estimates of population parameters,[1] the first analyses compared the univariate relationships between various measures of faculty activity and compensation.[2] Quartiles were used to form groupings of variables for cross-tabulation analyses to examine results by type of institution. Correlations between measures of faculty activities and compensation were also examined. Multiple regression analyses were carried out to study the combined relationships between faculty demographic characteristics, activities and workload, productivity and compensation for faculty in engineering and in the natural sciences.

RESULTS

Univariate analyses

This section examines the relationships between basic salary and various indicators of faculty activities, workload and productivity in teaching, research and scholarship, administration and public service.

Teaching/instruction. Teaching-related activities examined include the percentage of time spent on teaching and instruction, hours in class per week, student contact hours per semester and type of student taught (undergraduate students only, graduate students only or a mixture of both types) (see Table 1).

Percentage of time spent on teaching/instruction. Faculty who spend more of their time on teaching and instruction are paid less. Average basic salary varies in a linear pattern from a low of $34,307 for faculty spending more than 72% of their time on teaching, to a high of $56,181 for faculty spending less than 35% of their time on teaching. The same pattern holds for faculty in research universities, doctoral-granting institutions and comprehensive colleges; time spent on teaching is not related to basic salary for faculty in liberal arts colleges.

Hours in class per week. Faculty who spend the least time in class receive the highest pay. Average basic salary ranges from a high of $50,927 for faculty spending the fewest hours in class (less than six per week), to a low of $36,793 for faculty spending the most time in class per week (12 or more hours).

This pattern is essentially the same for faculty in doctoral-granting universities, comprehensive colleges and universities, other four-year institutions and liberal arts colleges. A U-shaped distribution defines the relationship between hours spent in class and compensation for faculty in research universities, where the highest salaries are earned by those spending the least time in class, the lowest salaries by those spending between six and 11 hours in class, and the second highest salaries being earned by those spending the most hours in class per week.

Student contact hours. The distribution of student contact hours per semester reflects a U-shaped curve. The highest income is earned by those with the least number of student contact hours, dropping to a low point through the mid-range of contact hours and rising again to the second highest salary for those with the most contact hours.

The same pattern holds for faculty in research universities. Similarly, faculty in comprehensive colleges and universities earning the highest pay have the fewest student contact hours. Student contact hours are not related to basic salary for faculty in doctoral-granting institutions, liberal arts colleges or other four-year institutions.

Type of students taught. Faculty who teach only graduate students are paid more than their counterparts who teach both undergraduates and graduate students, and those who teach only undergraduate students. The same pattern holds true for faculty in research, doctoral-granting and comprehensive institutions.

Research/scholarship. Measures of research and scholarship examined include percentage of time spent on research and scholarship, total refereed publications (career) and being a principal investigator on an externally-funded research project (see Table 2).

Percentage of time spent on research/scholarship. Faculty who spend the most time on research receive the highest compensation. Salaries range from a high of $48,711 for those spending the most time on research—34% or more—to a low of $36,963 for faculty spending less than 5% of their time on research. The same pattern holds by type of institution, except that time spent on research is not related to basic salary at liberal arts colleges.

Total refereed publications (career). Faculty who publish the most receive the highest compensation. Faculty with more than 30 career publications

[1] Population estimates from survey data were based on weights derived from the inverse of the probability of a faculty member in a particular type of institution being selected. The probability of selecting a faculty member for the sample was a function of the odds of an institution being selected from the universe of accredited postsecondary institutions, the probability of a faculty member being selected from the population of faculty within his or her institution, and the sampling rate for employment status (full- or part-time) and program area [18, p. 99].

[2] The cross-tabulation analyses by type of institution are available by writing to the author. All differences between means or proportions described in the text as 'significant' are statistically significant at a minimum of $p < 0.05$ (two-tailed test).

Table 1. Mean basic salary from institution for tenure-track, full-time faculty, by teaching-related variables, Fall 1987

Percentage of time spent on teaching/instruction		Number of hours per week teaching in class		Number of student contact hours per semester		Whether or not faculty member taught only undergraduate or only graduate students	
	Mean ($)		Mean ($)		Mean ($)		Mean ($)
<35%	56,181	<6	50,927	<110	49,267	Taught only undergraduate students	44,176
SE	914	SE	732	SE	712	SE	883
35–52%	42,935	6–8	43,191	110–217	38,442	Taught grad/undergrad students	41,478
SE	465	SE	488	SE	378	SE	287
53–71%	37,244	9–11	38,060	218–359	37,632	Taught only graduate students	56,661
SE	357	SE	503	SE	444	SE	1,365
72% or more	34,307	12 or more	36,793	360 or more	43,159		
SE	320	SE	433	SE	602		

Table 2. Mean basic salary from institution for tenure-track, full-time faculty, by research-related variables, Fall 1987

Percentage of time spent on research/scholarship	Mean ($)	Number of refereed publications (career)	Mean ($)	Status as principal investigator on research project	Mean ($)
<5%	36,963	<2	39,198	Not principal investigator	39,567
SE	549	SE	480	SE	284
5–15%	39,638	2–10	37,401	Principal investigator	51,517
SE	475	SE	355	SE	761
16–33%	44,062	11–29	42,869		
SE	588	SE	436		
34% or more	48,711	30 or more	56,183		
SE	620	SE	735		

earn an average basic salary of $56,183, whereas faculty with two or fewer publications earn $33,198. This pattern does *not* vary by institutional type: publications are as strongly related to compensation for faculty in liberal arts colleges and comprehensive institutions as it is for their compatriots in research and doctoral-granting universities.

Principal investigator. Being a principal investigator on an externally-funded research project means earning a substantially higher basic salary, $51,517 versus $39,567. The same pattern holds true for faculty in research universities, doctoral granting-universities, comprehensive colleges and universities and other four-year institutions. The relationship is not true for faculty in liberal arts colleges.

Administration and service. Beyond teaching and research lie faculty responsibilities in administration and public service (see Table 3).

Percentage of time spent on administration. Faculty spending the greatest time on administration earn the highest basic salaries. This relationship is true for faculty in research universities, doctoral-granting institutions and comprehensive colleges. The percentage of time spent on administration is only weakly related to compensation for faculty in liberal arts colleges; it is unrelated to compensation for faculty in other four-year institutions.

Percentage of time spent on public service. Faculty who spend the most time on public service tend to make lower basic salaries. There is no significant difference, however, when the relationship between public service and compensation is examined by type of institution.

Summary. Univariate analyses and cross-tabulations show that teaching is negatively related to compensation, whereas research is highly valued. These patterns hold true for faculty overall and, in most cases, for faculty in each type of institution.

Combined relationships between faculty salary, demographics, activities and productivity

The next set of analyses explores the combined relationships between faculty demographics and behavior with compensation to determine their relative importance in faculty salaries. First, the intercorrelations between compensation and faculty activities are described. Second, multiple regression models using basic salary as the criterion are examined for faculty in engineering and the natural sciences.

Intercorrelations for faculty activities with compensation. Intercorrelations between faculty activities and compensation are shown in Table 4. The correlations indicate that time spent on teaching is negatively related to compensation overall and for each type of institution except liberal arts colleges. Correlational analyses also support the finding that teaching only graduate students is positively

Table 3. Mean basic salary from institution for tenure-track, full-time faculty, by administrative- and service-related variables, Fall 1987

Percentage of time spent on administration	Mean ($)	Percent of time committed to public service	Mean ($)
<5%	38,491	<5%	42,738
SE	489	SE	307
5–9%	40,410	5% or greater	40,174
SE	588	SE	731
10–19%	41,720		
SE	466		
20% or more	48,546		
SE	688		

Table 4. Correlations between faculty activities, productivity, and basic salary from institution, by type of institution: all tenure-track, full-time faculty, Fall 1987

	Percentage of time on teaching/ instruction	Percentage of time on research/ scholarship
All institutions	−0.43	0.21
Research	−0.34	0.04
Doctoral	−0.27	0.16
Comprehensive	−0.33	0.06
Liberal arts	−0.06	0.13
Other four-year	−0.41	0.10
	Number of hours teaching in class, per week	Number of refereed publications, career
All institutions	−0.07	0.42
Research	0.06	0.38
Doctoral	−0.12	0.32
Comprehensive	−0.07	0.23
Liberal arts	−0.14	0.32
Other four-year	−0.04	0.35
	Student contact hours	Principal investigator on research project
All institutions	0.06	0.27
Research	0.06	0.18
Doctoral	−0.02	0.24
Comprehensive	0.04	0.12
Liberal arts	0.04	0.03
Other four-year	0.02	0.32
	Taught only undergraduate students	Percentage of time on administration
All institutions	0.03	0.22
Research	−0.03	0.20
Doctoral	0.08	0.10
Comprehensive	0.10	0.34
Liberal arts	0.02	0.05
Other four-year	−0.10	0.28
	Taught only graduate students	Percentage of time on service
All institutions	0.27	−0.07
Research	0.19	−0.02
Doctoral	0.26	0.01
Comprehensive	0.33	−0.02
Liberal arts	−	−0.08
Other four-year	−0.04	−0.19

related to compensation, overall and by type of institution. Unlike the univariate analyses, correlations indicate that hours per week spent in the classroom, student contact hours and teaching only undergraduate students are only marginally related to basic salary.

Correlations indicate that refereed publications are strongly, positively related to compensation, overall and by type of institution. Also positively related to compensation are time spent on research and being a principal investigator on an externally-funded research project, although the correlations are not as strong as those for career publications.

The percentage of time spent on administration is, for the most part, positively related with compensation. Time spent on service is unrelated to compensation, except at other four-year institutions where it is negatively related to compensation.

Multiple regression analyses. Multiple regression models for faculty in engineering and the natural sciences were highly predictive, accounting for 44 and 48 percent of the variance in basic salary (see Table 5).

Engineering. Engineering faculty are rewarded for doing more research and less teaching, publishing and being a principal investigator on an externally-funded grant. Senior faculty are paid more than their junior counterparts.

Natural Sciences. Faculty in the natural sciences are rewarded for following a graduate-oriented research and scholarship behavioral model. Especially important are publishing, bringing in funded research projects, spending more time on research and less on teaching, and focusing on graduate instruction.

Summary. Four predictors of compensation are common to engineering and the natural sciences: publishing, spending more time on research and less on teaching, being a principal investigator on a funded research grant and seniority. Spending

Table 5. Significant predictors of basic salary from institution, tenure-track, full-time faculty by program area, Fall 1987

Predictor	Engineering R-square = 0.44 n (unweighted) = 152				Predictor	Natural sciences R-square = 0.48 n (unweighted) = 481			
	Beta	SE	Standardized beta	p		Beta	SE	Standardized beta	p
Seniority	3044.83	803.57	0.30	0.0002	Publications (career)	3466.12	423.21	0.32	0.0001
More research/less teaching	3715.70	1196.78	0.28	0.002	Seniority	4655.53	551.92	0.31	0.0001
Publications (career)	3494.08	1161.73	0.22	0.003	Percentage of time, administration	4456.63	633.89	0.25	0.0001
Principal investigator, funded	1915.28	817.30	0.18	0.02	Principal investigator, funded	1709.99	549.30	0.13	0.002
					More research/less teaching	1743.35	634.63	0.13	0.006
					Taught only graduate students	1259.22	560.49	0.09	0.03

more time on administration and teaching only graduate students are also correlates of compensation for faculty in the natural sciences.

These results show no evidence of teaching being positively related to compensation. Teaching productivity (student contact hours per semester) is unrelated to compensation. Time spent on teaching is negatively related to pay.

DISCUSSION AND CONCLUSIONS

The findings demonstrate the dominance of the research and scholarship-oriented reward structure for all faculty in American four-year colleges and universities, including faculty in engineering and the natural sciences. Regardless of institutional type or mission, faculty who spend more time on research and who publish the most are paid more than their teaching-oriented colleagues. Univariate analyses show teaching as a negative factor in compensation, especially the percentage of time spent on teaching and instruction. Research-related indicators, especially teaching graduate students, publishing, and spending time on research, are positively related to compensation.

Multiple regression analyses for faculty in engineering and the natural sciences show a similar pattern. Research and scholarship remain the dominant predictors of compensation, with teaching either being a neutral or negative factor in compensation.

These results show virtually no support for teaching being a positive factor in compensation. Instead, teaching is either a negative factor [14] or a neutral factor [12, 13] in basic salary. In this context, attempts to enhance the quality of undergraduate engineering education by encouraging faculty to spend more time on instruction directly confront faculty reward structures which view research and publishing as the principal activities by which faculty should be judged. That teaching is not rewarded has ramifications for the attrition of students from engineering: recent research shows that lack of interest in teaching on the part of engineering faculty is a factor in the decision of undergraduate students to switch out of an engineering major [19]. Until academic leaders and their faculty decide to place a higher value on teaching and instruction, it is unlikely that external efforts to enhance undergraduate engineering education (or, indeed, undergraduate education in any field) will result in lasting change.

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