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Evaluation and Rewards for Faculty Involved in Engineering Design Education*

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One of the challenges of engineering education concerns the evaluation and reward of faculty who are primarily involved in design-related teaching and scholarship. Some engineering educators find themselves involved in creative synthesis or design activities that may be more difficult to measure or that are less readily accepted in academia than traditional analysis-oriented scholarly activities. Engineering faculty are often interested in teaching and doing research in the design aspects of engineering, yet there are limited methods for traditional peer review of these activities. As a result, some faculty may choose to take the route of teaching design, but, in the scholarly portion of their stewardship, as in the sciences, may choose to do analysis activities which are more readily accepted and more easily evaluated. If engineering design is to advance as a viable academic discipline, there must be an increased awareness of issues and practices associated with the scholarly evaluation of design-oriented faculty. A survey of methods used by mechanical engineering departments to evaluate scholarship of design faculty was conducted. Some principles and practices for evaluation of engineering design faculty are identified and conclusions are drawn.

INTRODUCTION

ONE OF THE CHALLENGES of education is how to evaluate and reward faculty. As in most disciplines, university engineering educators are expected to teach, perform creative research work and provide citizenship. Some engineering educators find themselves involved in creative synthesis or design activities that may be more difficult to measure or that may be less readily accepted in academia than traditional analysis-oriented scholarly activities.

Engineering faculty are often interested in teaching and doing research in the more applied design aspects of engineering, yet there are limited methods for traditional peer review of these activities. As a result, some faculty may choose to teach design, but in the scholarly portion of their stewardship, as in the sciences, do analysis activities which are more readily accepted and more easily evaluated. Interestingly, faculty commitment to their university is stronger in applied fields and considerably weaker in less applied fields [1].

If engineering design is to advance as a rewardable activity, there must be an increased awareness of the issues and practices associated with the scholarly evaluation of design-oriented faculty. Sharing the evaluation practices of departments across the country may be a first step towards achieving this awareness.

A survey of methods used by mechanical engineering departments to evaluate scholarship of design faculty was conducted. Some principles for evaluation of engineering design faculty are identified and conclusions are drawn. Our purpose in carrying out this survey is to foster more widespread innovation in the evaluation process and promote more design involvement of engineering faculty.

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EVALUATING AND REWARDING FACULTY

The importance of how faculty are evaluated and rewarded cannot be overstated with respect to its effect on engineering education. A National Science Foundation workshop stated the following:

> Critical to the quality of engineering education is a faculty that is diverse in cultural and professional experiences, that is committed to lifelong learning and scholarship, and that places primary emphasis on educating professionals. In particular, we must develop rewards and incentives that promote the contributions of all faculty and that signal clearly that they are valued colleagues . . . [2]

Researchers from the Pennsylvania State University's Center for the Study of Higher Education conducted 27 semi-structured one-hour interviews with deans, chairs, faculty, industry leaders and association officers who comprise the leadership of national engineering education societies and ABET. During these interviews, these leaders not only described what they believe are the two most significant changes in the field of engineering education during the last decade, but also what changes would need to be made to help other schools make similar changes. In the conclusion of their paper, the authors made the following statement:

> Two approaches to encouraging faculty to adopt changes in educational practice most commonly cited by the leaders were changing the reward structure [for faculty] and providing opportunities for faculty to learn about significant changes in educational practice by [having them attend] workshops or industry internships. [3]

Research activities are often found to be more significant in faculty evaluation than teaching or citizenship activities [4, 5]. Gorman *et al.*, in writing about this issue, state that:

> Many of the [Boeing] Fellows felt that teaching was not as important as research productivity when it came to Promotion and Tenure. Part of the problem may lie with the evaluation metrics: totaling the number of research dollars and archival publications achieved by a faculty member is easier than assessing the quality of teaching . . . Many of the [fellows] excelled in [research and grant dollars], but felt that the pendulum had swung too far away from honoring industrial experience and teaching excellence. Ideally faculty would have a number of paths to success, and those who regularly incorporated lessons from industry into their teaching would be promoted, especially if they shared those lessons with others by publishing, presenting at conferences and developing innovative educational materials. [6]

Peer-reviewed scholarly activities may be defined broadly as finding new knowledge or applying existing knowledge in new ways, but finding seems to offer more reward in traditional faculty evaluation methods.

Engineering as a discipline involves the use of analysis and synthesis skills to solve real-life problems, yet analysis skills often predominate as acceptable scholarly activity in academia, for a variety of reasons. Certainly one of the reasons is that it is easier to measure engineering science activities than it is engineering design activities. Yet many engineering programs are busy revising the style and substance of engineering curricula to provide increased attention to design as a result of an 'imbalance caused by too much emphasis on the analytical approaches of engineering science' [7].

Engineering in practice *is* essentially a creative process involving the application of existing knowledge, materials, tools and other resources to the solution of new and existing problems [8]. The essence of science is in finding new knowledge, whereas the essence of engineering is design [9]. 'A scientist can discover a new star, but he cannot make one. He would have to ask an engineer to *do* it for him' [10]. Engineers are expected to enter professional practice with a B.Sc. degree, much more so than other university majors. As they enter the workforce they are expected to be able to do engineering design and yet their faculty mentors are rarely rewarded in their creative work activities for this type of activity.

As long as faculty evaluation and reward systems give greater recognition to analysis activities than design activities, faculty will tend to pursue those activities that will provide the greatest reward. Boyer in his landmark book, *Scholarship Reconsidered*, stated: 'We conclude that for America's colleges and universities to remain vital a new vision of scholarship is required. What we are faced with, today, is the need to clarify campus missions and relate the work of the academy more directly to the realities of contemporary life.' In addition, he wrote:

> What we urgently need . . . is a more inclusive view of what it means to be a scholar—a recognition that knowledge is acquired through research, through synthesis, through practice, and through teaching. We acknowledge that these four categories—the scholarship of discovery, of integration, of application, and of teaching divide intellectual functions that are tied inseparably to each other. Still, there is value, we believe, in analyzing the various kinds of academic work, while also acknowledging that they dynamically interact, forming an interdependent whole. Such a vision of scholarship, one that recognizes the great diversity of talent within the professoriate, also may prove especially useful to faculty as they reflect on the meaning and direction of their professional lives. [11]

Of all of the disciplines in academia, engineering certainly should be able to lay claim to all of these four scholarly activities.

Boyer also strongly supports the concept of identifying appropriate evaluation and reward systems for faculty based on missions and outcomes that are desired for specific disciplines and programs. He attributes faculty stress and burnout to reward systems that do not meet these criteria.

On the brighter side, there are several drivers promoting change in engineering education, including some shift in the way faculty are evaluated and rewarded. These include reports by the National Academy of Engineering, the American Society for Engineering Education and the National Research Council [12]. Another driver for change has been ABET 2000, driven at least in part by industry input and industry working with academia directly [13]. In addition, faculty themselves tend to favor a more flexible system that rewards not only traditional analysis research activities, but also other activities [14].

SURVEY OF ME DEPARTMENTS

Previous researchers have surveyed university faculty concerning faculty reward systems and how faculty spend their time in engineering research [13, 15]. As reported by Jianping Shen, in general 'There is a discrepancy between presumed, multidimensional expectations for faculty members and the unidimensional reward structure. In essence, there is a tension between what is expected and what is rewarded' [16].

In order to better understand the current situation regarding the evaluation of design-oriented faculty, a survey of Mechanical Engineering departments across the United States was conducted. A short survey, described below, was sent to the chairs or heads of each department as listed in the American Society of Engineering Education directory. The survey was designed around four main areas of interest as we began to explore the topic of evaluation and rewards:

1. *Demographics and operation of the departments*. We wanted to know the percentage of faculty that are primarily design-oriented and how that compares to the research and graduate education emphasis of the department. We asked if the department had a document specifying reward criteria for ME and if so how it is specific to this discipline. We hoped to see if there was anything particularly related to design.
2. *Evaluation and rewards for design-oriented faculty*. In this area we wanted to better understand how various scholarly products are viewed and reviewed by the departments. We then asked for a comparison of the rewards for design-related activities compared with engineering science related activities.
3. *Suggestions for innovation*. Here we asked respondents to provide an indication of how their evaluation and reward practices fostered innovation, especially in design, and then asked them for any innovative design activities or products that had been rewarded in their department.
4. *Summary*. As an integration of the previous questions, we asked if the chairs would encourage or discourage new faculty from pursuing design-oriented scholarship.

Clearly the survey is just a start in beginning to understand ways to promote and reward design-oriented scholarship. The results of the survey are described in the next section.

SURVEY RESULTS AND COMMENTS

At the time of publication there were 27 responses to the survey. Results of the survey are summarized below with an emphasis on comparisons of responses that are of interest to the topic of this paper. A copy of the survey and the complete response data are available from the authors.

Figures 1, 2 and 3 summarize data on the percentage of faculty that would classify themselves as primarily engaged in design-oriented scholarship and compares that percentage with the average time spent on research and the self-assessed focus of the department on undergraduate vs. graduate education.

Interestingly, there were four respondents that indicated that all of their faculty are primarily involved in design-oriented scholarship. Comparing this percentage to the percentage of time spent on research shows the general trend of higher research levels being associated with fewer design faculty. A similar, but weaker trend is exhibited with an emphasis on graduate education.

In Figs 4 and 5 the percent of time spent by faculty on research is compared to the relative *value* placed on research (one being the lowest and 7 being the highest) and the difference between the value placed on teaching and research. The plotting of the difference is intended to help normalize the responses.

Figures 4 and 5 show some expected correlation with the time spent on research and its relative value, as perceived by the faculty of each department. What we want to point out here is that faculty generally spend time on what is valued. This is likely just as true for design activities as it is for teaching.

Also in this section of the survey respondents were asked if their department had a document, separate from the university document, that described specific criteria for evaluating and rewarding faculty within their discipline. Only 4 out of 26 respondents indicated that they had such a document, and none of the documents contained discussion specifically directed towards design-related activities or products.

Figures 6, 7, 8 and 9 focus on the evaluation and rewards for Design-Oriented faculty. Figure 6 shows that, on average, technical journal articles

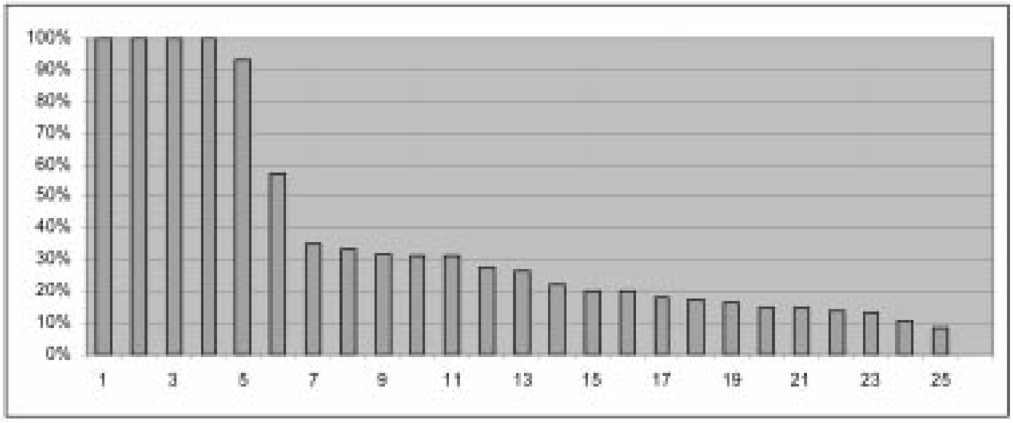

Fig. 1. Percentage of faculty that would classify themselves as primarily design researchers and/or educators for each respondent.

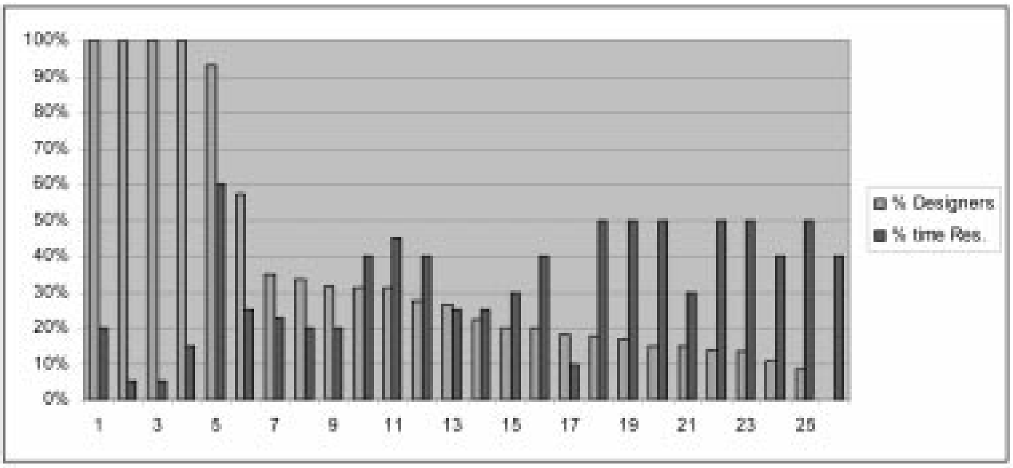

Fig. 2. Percentage of faculty that consider themselves as designers compared with the percentage of time that faculty spend on research-related activities for each respondent.

still carry the most weight, with industrially-oriented products being of less value—even for design-oriented faculty. Figure 7 displays the extent to which the criteria for evaluating and rewarding faculty foster educational objectives—especially those related to design. Figure 8 provides some examples of the wide range of relative importance from department to department. In Fig. 9, the relative value of review by industry/market compared to academic peers is shown. The most common response is that industry review is less valued, but a surprisingly large number of respondents indicated that it has more value.

Table 1 indicates that there is a wide variety of opinions on the value and risk of pursuing design-oriented scholarship. Responses at the extremes of both strongly encouraging and strongly discouraging are displayed along with strong comments on both sides of this issue.

CONCLUSIONS

Evaluation and reward systems for engineering faculty have a strong influence on determining what types of activities they will pursue in their stewardships. How scholarship is defined at an institution can have an important influence on expectations.

Engineering design is an important aspect of engineering. Faculty involved in teaching and conducting research in engineering design need an evaluation and reward system that encourages these design activities and their excellence, as well as analysis activities.

Conclusions from the brief survey conducted are as follows:

1. Approximately a quarter of the mechanical engineering chair/head respondents felt that nearly all of their faculty would consider themselves to be design-oriented. The remaining three-quarters of the respondents felt that less than 30% of their faculty would consider themselves to be design-oriented. There is clearly a wide range of perception of faculty involvement in design.
2. In general, schools reporting the highest percentage of their faculty involved in design are less involved in what they consider to be

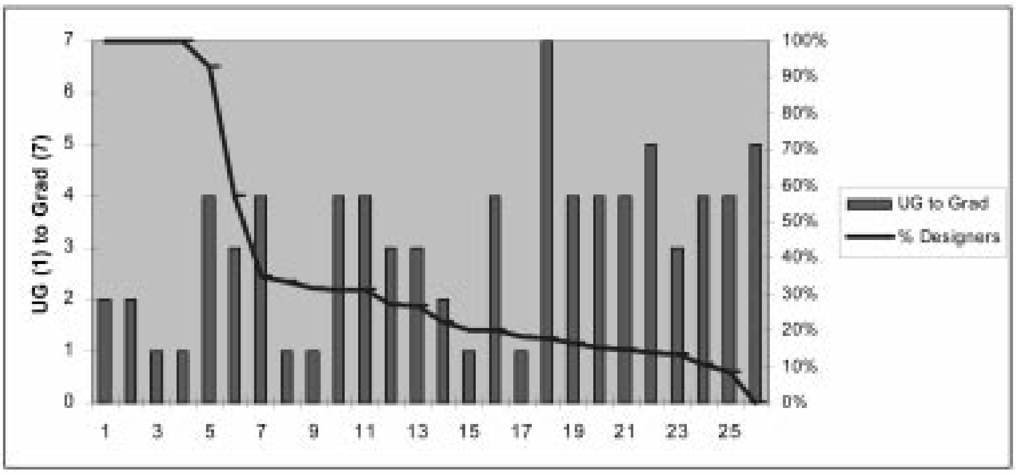

Fig. 3. Percentage of faculty that are designers compared to the primary mission of the institution for each respondent.

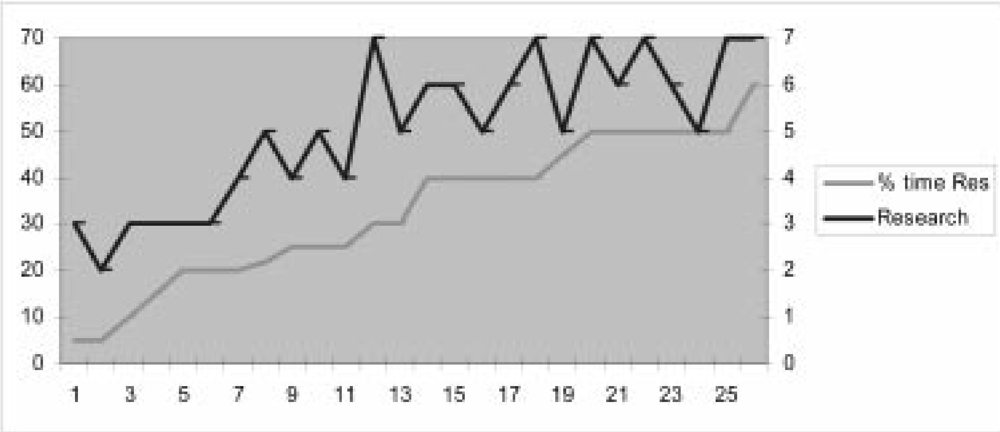

Fig. 4. Percentage of time spent in research activities compared to the relative value placed on scholarship ('7' being the highest) for each respondent.

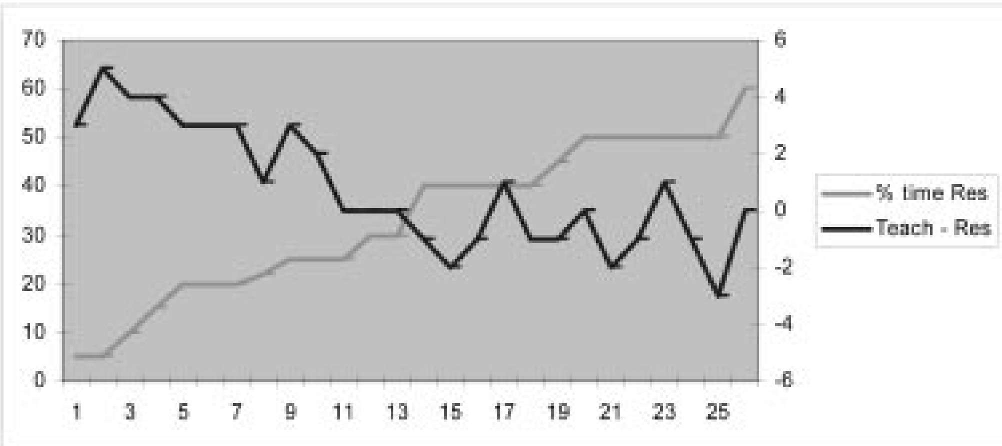

Fig. 5. Percentage time spent in research activities compared to the difference in the relative value placed on teaching and scholarship (positive being a higher emphasis on teaching) for each respondent.

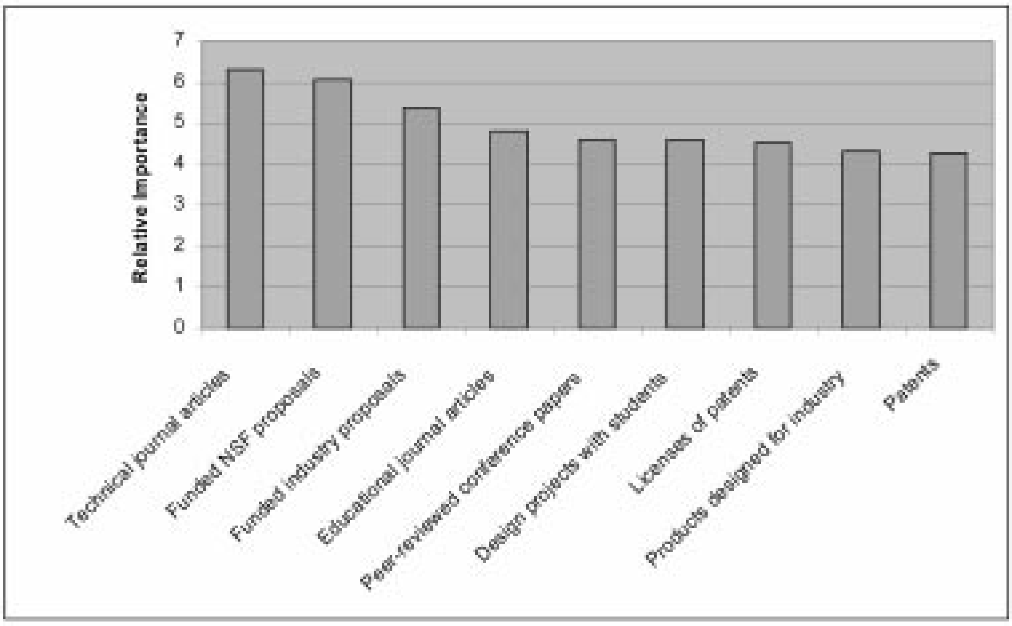

Fig. 6. Average relative importance of various scholarly products/activities when evaluating design-oriented faculty, ranked in order of importance.

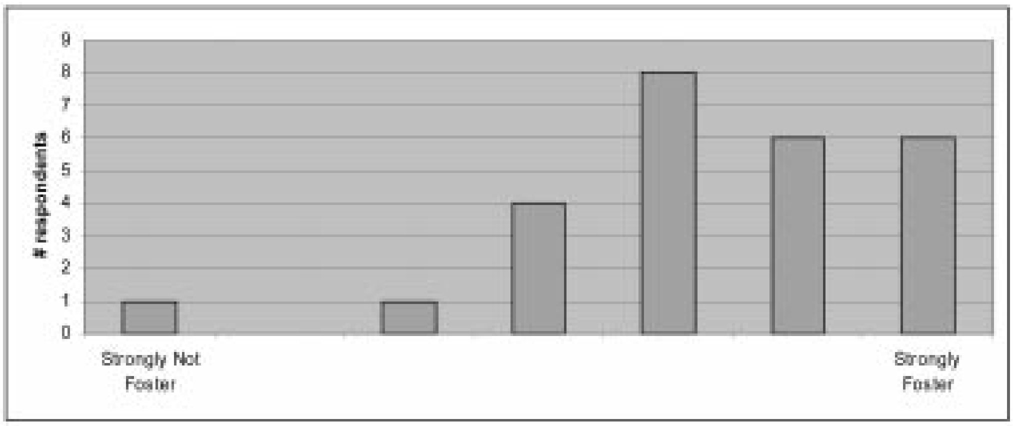

Fig. 7. Extent that the criteria for evaluating and rewarding faculty foster educational objectives—especially those related to design.

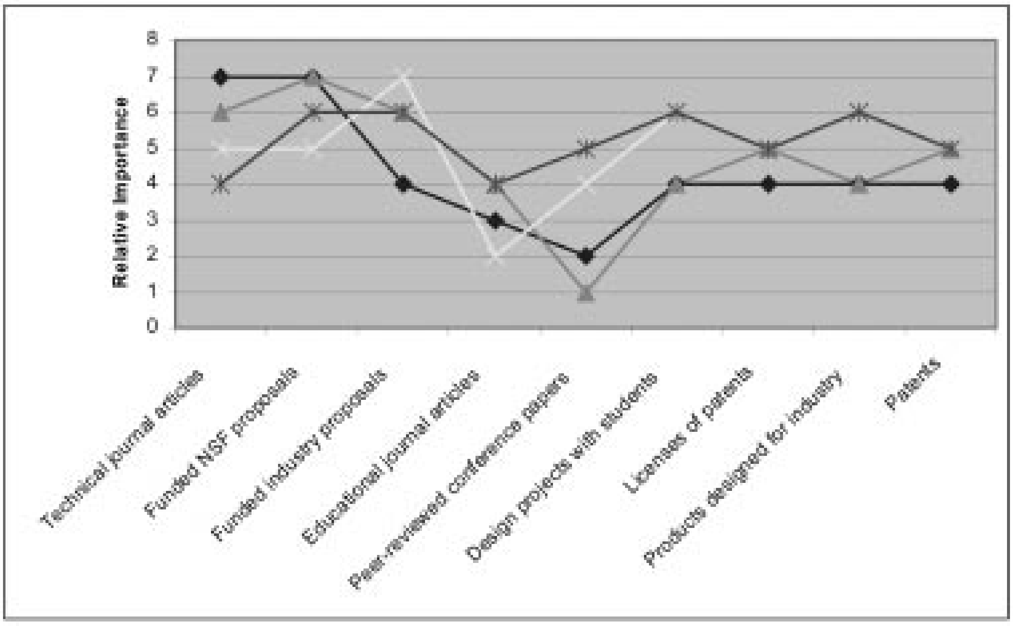

Fig. 8. Relative importance of various scholarly products/activities when evaluating design-oriented faculty for four departments with different levels of importance for technical journal articles. Products/activities are in the same order as Fig. 6.

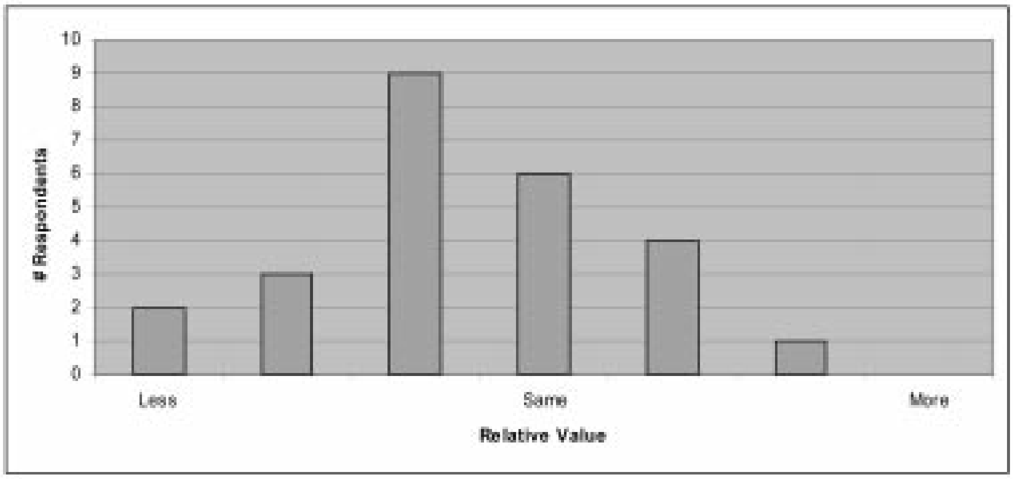

Fig. 9. Relative value of review by industry/market compared to faculty peer review.

Table 1. Response to the question 'If one of your new faculty seeking tenure expressed interest in focusing his/her scholarly activities and/or teaching in engineering design, would you encourage or discourage them?'
('1' being strongly encourage and '7' being strongly discourage)

1	Most often, engineering design can be open-ended; this means that one design problem can have multiple solutions and still be correct. It gives both faculty and students the opportunity to reason beyond established imaginary boundaries.
1	Good design faculty are essential for engineering education.
1	We believe that design education is really what engineering education is about.
1	Our institute focuses on undergraduate education and the capstone design sequence (4 courses) is a highly valued component of our program.
2	Design has some very challenging needs and leads to types of research that should be done.
3	Our curriculum is design-oriented and so faculty must have experience in design.
3	Only a faculty member with a strong background in engineering science has a good potential to become a viable educator in engineering design.
4	Viewed as the same relative value as other areas of teaching or research.
4	I think you can be as successful in design as in any other area. The work of the individual is the most important component.
4	This would be a faculty choice, and, so long as they achieved the objectives of the program and showed productivity, then it will go well.
7	This is the role of engineering technology.
7	Design is at the core of engineering.
7	The risk of their not receiving tenure is too great.
7	I believe it is worthwhile and needs some mentorship from senior faculty members.

'research oriented activities' and schools with higher levels of research are associated with schools with fewer design faculty. A similar but weaker trend exists with an emphasis on graduate education.

3. The survey results show that faculty time spent on teaching and/or research is mainly a function of what is valued by the institution.
4. Only about 15% of the respondents had a separate document defining faculty evaluation and rewards for their discipline. None of the documents were specifically directed toward design-related activities or products.
5. In general, technical journal articles, as scholarly products, still hold the most value, but other products can also have significant value, depending on the institution and its perceived mission.
6. Industry review of scholarly products is seen as less valued than peer-reviewed products, but a large number of respondents indicated it has more value.
7. There appears to be a wide range of strong opinions on the value and risk of pursuing design-oriented scholarship for tenure-seeking faculty.

No doubt, additional research is needed on this important topic in engineering design education.

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REFERENCES

1. Y. Neumann and E. Finaly-Neumann, The reward–support framework and faculty commitment to their university, *Research in Higher Education*, **31**(1) (1990).
2. *Restructuring Engineering Education: A Focus on Change*, report of an NSF Workshop on Engineering Education, Division of Undergraduate Education, April 1995.
3. M. E. Gorman *et al.*, Transforming the engineering curriculum: Lessons learned from a summer at Boeing, *International Journal of Engineering Education*, **90**(1) (2001) pp. 143–150.
4. P. J. Gray, R. C. Froh and R. M. Diamond, A national study of research universities on the balance between research and undergraduate teaching, Center for Instructional Development, Syracuse University, May 1992. The authors summarized this report in Myths and realities, *AAHE Bulletin*, **44**(4) (1991) p. 4.
5. R. M. Felder, R. Brent, T. K. Miller, C. Brawner and R. H. Allen, Faculty teaching practices and perceptions of institutional attitutes toward teaching at eight engineering schools, *Proceedings of the 1999 Frontiers in Education Conference*, ASEE/IEEE, Phoenix, AZ, November 1998.
6. S. A. Bjorklund and C. L. Colbeck, The view from the top: Leaders' perspectives on a decade of change in engineering education, *International Journal of Engineering Education*, **90**(1) (2001) pp. 13–20.
7. B. Seely, The other re-engineering of engineering education, 1900–1965, *International Journal of Engineering Education*, **88**(3) (1999) pp. 285–294.
8. J. F. Blumrich, *Science*, **168** (1970) pp. 1551–1554.
9. G. Dieter, *Engineering Design*, McGraw-Hill, New York (2000).
10. G. L. Glegg, *The Design of Design*, Cambridge University Press, New York (1969).
11. E. Boyer, *Scholarship Reconsidered: Priorities of the Professoriate*, Carnegie Foundation for the Advancement of Teaching, Princeton, NJ (1990).
12. J. W. Prados and S. I. Proctor, What will it take to reform engineering education?, *Chemical Engineering Progress*, **96**(3) (2000) p. 91.

13. R. H. Todd, C. D. Sorensen and S. P. Magleby, Designing a senior capstone course to satisfy industrial customers, *International Journal of Engineering Education*, **82**(2) (1993).
14. J. A. Lee, D. M. Castella and S. G. Middleton, Faculty perceptions of academe's evaluation system, *International Journal of Engineering Education*, July (1997).
15. N. Kannankutty, R. Morgan and R. Strickland, University-based engineering research in the United States, *International Journal of Engineering Education*, April (1999).
16. J. Shen, Mission involvement and promotion criteria in schools, colleges, and departments of education, *American Journal of Education*, **105** (1997).

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