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ABSTRACT

This paper presents guidelines for evaluating university research scientists. Each scientist should know the standards of performance that are used in the evaluation, the job segments that are being evaluated, and the relative weight assigned to each job segment. Five job segments are identified: (1) impact of research findings; (2) number of publications; (3) resource self-sufficiency; (4) graduate education; and (5) service. A detailed discussion of each job segment is presented and includes questions and concerns from a variety of perspectives. (Contains 21 references.) (Author/DDR)

TITLE: EVALUATION OF PERFORMANCE OF UNIVERSITY RESEARCH SCIENTISTS.

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EVALUATION OF PERFORMANCE FOR UNIVERSITY RESEARCH SCIENTISTS.

Research scientists go to great lengths to ensure that their work is objective. They design experiments to test hypotheses, put the variables or conditions into effect, and count, measure or collect samples to determine the outcome. The results are summarized, often subjected to statistical analysis and prepared for publication. A manuscript is usually internally reviewed and then submitted to a journal for external review.

During this process there are guides to keep researchers on the right path. We usually discuss our research with others while it is in the planning stage and get opinions about our ideas. The scientific method provides a framework for the conduct of the research, modified to meet the particular practices of our discipline. Journals usually have criteria that reviewers use to evaluate manuscripts that have been submitted. Though we may question the objectivity of the process when our manuscript has been dissected by a reviewer, the whole process is fairly well understood by most of those involved, is straightforward and is usually fairly comprehensive and objective.

Evaluation of the performance by a research scientist should have many of the same characteristics. Each scientist should know the standards of performance which are being used. Eight characteristics of effective standards [1] have been summarized:

1. They are based on the job and not the person(s) in the job.
2. They are achievable.
3. They are understood.
4. They are agreed on.
5. They are as specific and measurable as possible.

6. They are time-oriented.

7. They are written.

8. They are subject to change.

The premise is that effective standards increase the performance of an individual. If the evaluator and scientist being evaluated jointly develop the standards, fewer problems occur. The evaluator and scientist will both understand the goals of the institutional unit and also the objectives of the scientist. Scientists can then devote all of their energy to accomplishing objectives rather than divert some energy to second-guessing what an evaluator really expects [2]. When openness and merit are cornerstones of evaluation, there should be no surprises and more positive emotions at the time of performance evaluation [3].

Standards of performance can be developed for scientists engaged in research activities at a university. Some scientists object to a detailed evaluation, lest we become "bean counters". However, research scientists are by training and aptitude bean counters in their profession, because they evaluate and solve problems by counting and measuring. During evaluation of a scientist, beans are always being counted in assessing performance and distributing rewards. In this process, it is important that the evaluator distinguish between a lima bean and a soybean and that the scientist being evaluated knows what the criteria are.

Research scientists have two missions. One is to add value by solving problems. Applied research is aimed at removing obstacles that have an immediate economic impact. Basic research is focused on solving important scientific questions that may not have immediate or foreseeable economic significance.

A second mission of research scientists is to train future scientists. Graduate students must be guided in acquiring knowledge that is already known in a discipline. They must be coached in learning skills and procedures that will enable them to acquire new knowledge and make it available to others. Adviser assistance is usually needed in procuring their first position.

When estimating the value added by a researcher, it is important to distinguish between activities and results [4]. An analogy can be drawn from the exploration for oil. Efforts are made to maximize the possibility for locating a profitable source of oil. These include an examination of geologic characteristics, seismic exploration and an assessment of other wells in the area. When a promising site is located, a well is drilled and casing is put in place. All of these activities are an expense. A flow of oil large enough to pay expenses and yield a profit is the desired result. Too many unsuccessful attempts will bankrupt a company.

Research also has activities and results. Planning research, writing grant proposals, conducting experiments and preparing manuscripts are examples of activity. Being awarded a research grant or solving an important problem are examples of results. The value of the results must outweigh the cost of the activities for long term success.

Evaluations should be made by those with the qualifications and willingness to make judgements about the scientific contributions of an individual. Part of the evaluation can be based on quantity and part should be based on quality of production. Scientific discoveries from a laboratory are different from cars from an assembly line. Each car has approximately the same value, so it is important to produce as many similar cars as can be sold. In contrast, a scientist's lifetime contributions can be fairly accurately gauged by examining the 10 best publications.

Performance evaluation should be based on several criteria related to quantity and quality. For applying standards of performance, job segments can be identified [1] for research scientists. Such segments might be to:

1. Investigate and solve problems pertinent to your area of expertise.
2. Disseminate information gained from research through journals, books and magazines and by presentations at meetings.
3. Develop extramural sources of funding for research.
4. Recruit and develop graduate students.
5. Develop a service component by serving on appropriate committees and editorial boards.

Impact of Research Findings

Assessing quality is much more difficult than assessing quantity. A model that might serve as a model to assess quality is described in a Taxonomy of Educational Objectives [5]. This model deals with recalling knowledge and developing intellectual capabilities. Six major categories of knowledge, comprehension, application, analysis, synthesis and evaluation are developed. The premise is that these categories exist in a hierarchy and that greater intellectual abilities are required to complete higher order tasks. Higher order tasks are more difficult to complete, but successful completion of the higher order tasks adds more value.

Scientific contributions might also be considered in terms of hierarchical order. Some scientific discoveries add more value than others. One might visualize scientific discoveries as breaching a series of walls. A wall of ignorance separates the known from the unknown. Only a few individuals have the knowledge, technical ability and intuition to visualize what is beyond the wall. However, once the wall is breached, a larger number of individuals can participate. Some will rush through to explore the new territory that is now accessible, while others may dismantle the wall in order to build something new. Eventually a new wall will be encountered and the process repeated. Details of the genesis of one important discovery have been shared [6].

To develop the concept of hierarchical value, an example might be drawn from the study of vitamins. In 1900, scientists were not aware of an animal's need for nutrients called vitamins [7]. The need for sources of carbohydrate, protein, fat and some minerals was known. During the following years it became apparent that foods contained nutritional factors that were needed in very low concentrations to prevent or cure disease.

These initial discoveries breached a wall of ignorance about vitamins and opened the way for numerous other discoveries. Realizing that the discovery of the first vitamins suggested that there were more, scientists continued to search for and find vitamins over a period of approximately 50 years. Discovery of these later vitamins might be considered one order lower in the hierarchy than discovery of the original concept of vitamins. Accomplishments such as discovering the structure, the mode of action, and the nutritional requirement in the first species of animal might be assigned the next lower order. Determining the requirement in the diet for other species of animals might be one order lower.

The value of each order in relation to others does not appear to be an arithmetic progression. Value added by each successive order might more accurately be described by a logarithmic progression. Research that determines the dietary nutrient requirements of an animal might be assigned a value of 10^0. Discoveries in the ascending orders might be assigned values of 10^1, 10^2, and 10^3. Papers that detail discoveries at the top of the hierarchy add an immense amount of value to basic research.

Paths to discoveries at the top of the hierarchy are varied. In some cases, researchers have stalked a scientific answer for decades, producing a long publication record. In other cases, the first-listed author had almost no publication record. The discoverers of insulin [8], structure of DNA [9], and polymerase chain reaction [10] fit into this category.

For evaluating the impact of research findings, there are now quantitative aids. One way is to count how often an author's research has been cited during the past few years [11]. This method, which is a summary of short-term interests of scientists, would probably not have evaluated the importance of "jumping genes" [12]. The count could be based on citation rate by other scientists only, or on citation rate by other scientists plus citation by an author of his/her own research. The author of a well-accepted method or review article generally fares well using this method of evaluating impact.

Another quantitative aid for evaluating impact of research is to assign an impact factor to journals [13]. If research is published in a journal with a high impact factor, the research may be regarded as of better quality than research published in a journal with a low impact factor. While there is validity to this approach, it is important to avoid the stereotype that all research published in journals with high impact factors has a high impact and that all research published in journals with a low impact factor will have a low impact.

Some questions that need to be answered about the impact of research findings are: Where does the research of the scientist appear to fit in the hierarchy of that particular area of expertise? If the problem is solved, how much value will be added to the economy or to the knowledge of basic science? What is the rate of progress on solving the problem? Sometimes a well-designed and promising plan of attack on a problem yields little useful information. Such an outcome would be evaluated considerably less favorably than an outcome that adds a large amount of value. An element of risk enters at this point. Should a scientist attempt research with low risk and low return or should research be attempted that has the possibility of high risk and high return? The results, and not the activities, should be evaluated.

Number of Publications

Authorship of scientific publications is usually the main standard to estimate quantity of research. If this is done, the relative value of different types of publications should be stated. For certification purposes, the relative value assigned to different types of publications [14] is as follows:

Research/review paper in peer-reviewed journal	1
Commercial books (>96 pages)	2
Book chapters	.8
Abstracts/posters at meetings or conferences	.4
Case report	.3

The relative value of publications could be different for each administrative unit but should be uniformly applied to all researchers. The number of publications of each type can be multiplied by relative value to determine publication units(PU), which can then be added.

Concerns have been expressed about the importance that is sometimes attached to numbers of publications. Reviews of an individual for promotion and tenure, for a grant proposal, or for recognition are often greatly influenced by the quantity of the publication record, rather than by the quality. A desire to expand the publication list leads to questionable practices. One has been a significant increase in number of authors per journal article [15]. This may occur because present research problems are more complicated and require more areas of expertise and/or because authorship is unjustified. A second problem is wasteful publication. Results of a study may be subdivided into several publications rather than presented in one more extensive article, or the same study may be presented in different journals by different authors [16]. In addition, approximately half of published papers were not cited in the five years after publication [17]. Each time the peer-review and publishing process is engaged, costs are incurred in time and money.

Some institutions have taken steps to decrease the importance of quantity and increase the importance of quality during the process of evaluation. A suggestion was to limit publications to the three best articles in a year, with no more than 10 for a five-year period [18]. The National Science Foundation permits only five publications listed for a grant application [17]. This limitation directs attention to the quality of research.

For someone outside the researcher's administrative unit, opinions about a scientist's research may be based only on counting publications. Results of different ways of counting have been presented [19]. However, within an administrative unit, an annual evaluation of a research scientist should be more detailed. The acceptance of a peer-reviewed paper is based upon its content, not upon the number of authors contributing. Evidence of this fact is that many journals have instituted a review process that includes removal of the names of authors and their affiliation. The number of authors has no influence on the acceptance or rejection of the manuscript. It is the contribution of the manuscript that is judged. Therefore, the manuscript becomes the PU, and the authors should be credited a fraction based on their contribution. The total number of PUs in an administrative unit should be the same if summed from types of publications or from contributions of individual scientists.

Another benefit results from assigning scientists a fractional value of a publication. Most university research scientists have responsibilities for more than one type of scholarship [20]. Teaching has not experienced the inflation in number of teachers per course that research has experienced in number of authors per paper. Therefore, using deflated numbers for both teaching and research permits a fair evaluation of a faculty member's contributions.

It is possible to compare the capabilities required for various types of evaluation. Suppose that a list of 100 scientific publications, together with authors, was compiled from a department. The most simple type of evaluation would be to search for an author's name and count one additional number each time that author's name is located. Most children who have completed the second grade are capable of such evaluation.

If someone was to assign a fractional value to each publication or author of a publication, additional skills would be needed to complete the evaluation. Children with mathematics competency of sixth or seventh grade would be needed to add the fractions.

If the evaluator should be able to read and comprehend the information in the publications, additional capabilities are needed. Upperclassmen studying toward a Bachelor's degree could generally complete such an evaluation.

If the evaluator is expected to understand information in a publication and make a judgment about the value added by the information, a higher level of capabilities is required. Some, but not all, scientists with a Ph.D. are capable of such evaluation at the time they receive the degree. It is appropriate that higher order thinking be applied for a significant portion of the evaluation. Scientists, like others, tend to live up to, or down to, expectations.

Resource Self-sufficiency

Research is expensive. Minimum costs include the salary and fringe benefits of the scientist, and they should be evaluated on the basis of quantity and quality of contribution. Almost certainly there will be additional personnel costs for secretarial and technical assistance. Properly equipping a laboratory for some types of research is a major expense. Ongoing research consumes supplies and services which may be very expensive.

Money for research activities may come from intramural or extramural sources [21]. Intramural funds, mostly from tax sources, are received by the institution and distributed to support research. They typically support the barest essentials of a research program. Some research scientists are able to solve problems and add to knowledge with only a meager budget, while other scientists require a much larger budget. Those who require additional funds to conduct research usually must acquire them from extramural funds. Competitive grants from government agencies supply most of this money, but lesser amounts are received from business and industry and other private sources.

The ideal situation for an institution is to be affiliated with a productive scientist who costs the institution nothing financially. To determine the costs incurred by each scientist, a system of record keeping is required. Costs of personnel, equipment and supplies must be determined. The ability of a scientist to offset these costs with extramural funds can be determined. In this manner a scientist would be compared to his peers for efficiency of using research funds.

The research scientist then has choices. Spending more time to attract extramural funds may detract from excelling in other job segments. Building a larger research program will cost more than building a smaller one. The research scientist must make choices about the combination of effort and money that will result in a most advantageous evaluation. For the evaluator and scientist, this part of the evaluation adds the dimension of accountability for the use of financial resources.

Graduate Education

Developing the next generation of scientists is also a mission of research scientists that should be evaluated on the basis of quantity and quality of contribution. The adviser is important in guiding a student through the transition from an undergraduate student to an advanced degree holder. Many undergraduates are passive consumers of information. As they develop, they become producers of information. The adviser needs to provide individual attention so that the student can succeed in his/her academic program, can contribute to projects within the academic unit, and can learn the process of solving problems.

The ability to recruit well-qualified students is an important attribute of a scientist. A student with a good academic background, good intellectual abilities and good people skills can quickly make contributions within the academic unit. Students with deficiencies in one or more of these areas take longer to develop to the point where they are net contributors to the system. More adviser effort is required to assist the progress.

Another characteristic of a good adviser is the ability and willingness to develop the talent a student has. Students should not be accepted for graduate study if they do not appear capable of completing a degree. However, once accepted, the student should receive appropriate advice and encouragement that will enhance the probability of successfully completing a degree. Students may take slightly different routes and different lengths of time to complete the degree, but they should all meet appropriate minimum standards. Although an adviser should be an advocate for the student, if it becomes evident that a student cannot meet the requirements of the degree, then the adviser should act to bring about an amiable conclusion to the partnership.

The adviser can also be judged on the success of former students. If quality students enter a quality graduate program, receive quality advising, and enter a job market that has a scarcity of people, chances for career success are very high. If one or more of those conditions is less than optimal, chances for career success decrease. The adviser can have an important influence during the period of graduate study and in the assistance to acquire a first position. Some of the success of former students should rightfully be attributed to the adviser.

Service

A small but specified portion of the evaluation should be based on service activities. There are small jobs that need to be done in organizations that may benefit others more than the one who completes the job. If these jobs are evenly distributed, then no one is burdened. If some fail to do their fair share, others may accept more than their fair share in order to accomplish what is needed.

The research scientist should be informed of the relative value attributed to various service activities. How does the importance of chairing the Graduate Studies Committee in the unit compare to serving as a reviewer for a journal? What about responsibility for organizing sessions at national meetings or specialized conferences? Should one serve as a section editor or editor of a journal? How important is it to become an officer of a national or international organization?

Service activities that require more time and have more responsibility require more planning. If the scientist has the desire, does the evaluator encourage such a commitment? If so, years of development and participation are usually needed before achieving such an end.

Just as in the other areas of evaluation, an individual's service performance may range from outstanding to poor. Standards for service should have dimensions for quality and quantity.

Defining Expectations

Differences of opinion exist, and are often strongly defended, about job segments to be evaluated, standards of performance to be used in evaluating each segment, and relative weight assigned to each segment. The basis for these decisions should be the mission of the administrative unit. Some difference will probably exist among individuals in relative weight assigned to each segment; however, the fractional contribution by each individual should add up to the desired effect for the total unit. For evaluators who are more authoritarian, these decisions will be made by the evaluator. For evaluators who are more democratic, these decisions can be made after discussions with the whole group of scientists and then with individuals. Because the objective of evaluation is to improve job performance, the above information should be clear to all who are being evaluated.

The evaluation suggested requires time and effort. For the evaluator, a guide might be as follows: calculate the average salary of those of similar academic rank in the unit; express your salary as a percentage of that average salary; subtract 100 to find the percentage of time to be devoted to evaluation. While this amount of time may appear excessive, it can be productive use of time. Spending an appropriate amount of time and effort collecting information for evaluation of scientists will probably result in a more productive unit that can solve problems more efficiently and train future scientists better.

SUMMARY

Guidelines for evaluating university research scientists are described. Each scientist should know the standards of performance that are used in evaluation, the job segments that are being evaluated, and the relative weight assigned to each job segment. Five job segments have been identified.

1. Impact of research findings

Research efforts will produce varying amounts of impact. In most disciplines, a hierarchy of impact can be constructed. Findings that are closer to the top of the hierarchy have substantially more impact than findings at the bottom. Important discoveries in the basic sciences generally uncover new areas for research. Important discoveries in applied research usually solve problems that have a large economic impact. Evaluation of this component is based on prior discoveries and on the likelihood of significant discoveries from ongoing research.

If rate of citation or impact factor of a journal is used to establish impact of research, details of the procedure should be specified.

2. Number of Publications

A prescribed value is attached to each class of publication. If a referred journal article is assigned a publication unit of 1, then books could be assigned a value of 2, book chapters .6, abstracts/posters at meetings .4 and case reports .3. Each contributing author is then assigned a fraction of the publication unit based on proportion of contribution.

3. Resource self-sufficiency

Research is expensive and money should be used efficiently. To encourage efficiency, the money that an institution uses to support a research scientist can be compared to the money that a research scientist is able to obtain from extramural funds. The salaries of the scientist and supporting personnel are costs. The cost of supplies, equipment, and services from the institution should be included. These costs could be compared to revenue from extramural funds and some product that might be generated as a result of the research program. The net result from individual scientists can be compared.

4. Graduate education

Training future scientists is an important function of research scientists. The ability to recruit well-qualified students, develop their abilities and assist them in acquiring appropriate positions should be evaluated. Numbers of students advised to graduate degrees and quality of the students are important considerations.

5. Service

Some activities and duties benefit organizations more than individuals. Research scientists should be willing to assume their fair share of activities such as Graduate Studies Committee Chairman, reviewers for journals, and service in national organizations. Quantity and quality of contributions should be considered.

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