

dicted, Greenstein comments that this mode of teaching is more suited to special-topic courses.

A type of physics seminar that has been taught at Swarthmore College for over 70 years combines the active learning done by students in Greenstein's seminar with the more predictable pace characteristic of lecture courses. In a sense this mode of instruction bridges the gap between the traditional lecture course and the special-topic seminar. Such seminars may be of interest to faculty desiring to break out of the mold of lecture courses.

William C. Elmore described the Swarthmore physics seminars in a PHYSICS TODAY article about 25 years ago (March 1968, page 32). Each seminar typically consists of no more than nine students, who meet once a week for at least three hours. At the end of each seminar meeting the instructor hands out assignments for the next meeting. Usually these consist of some reading in the textbook and some problems, which all students are required to do; a few presentations that individual students are to prepare; and several problems that individual students are to present. When the seminar next meets, the students take charge and determine how they want to use the assignments to make sure the material is properly discussed and understood by all. The options include general discussion of some of the more difficult concepts, presentations followed by questions and discussion, and presentations of the problems with significant discussion, as well as conversation concerning how the material is related to other concepts they have learned. Each student understands that he or she shares the responsibility not only for his or her own learning but for the learning of others in the seminar. Most students are not afraid to speak up when they don't understand something or think ideas have not been made sufficiently clear.

As Greenstein mentions concerning his seminar, the students sometimes lose track of the important ideas and it is up to the instructor to lead them back on track without resorting to lecturing. Once in a while the students are not able to understand some portion of the material or resolve an argument. Here again the instructor must attempt to give them direction without telling them the answer. The meeting ends when all of the material has been covered to the satisfaction of both the students and the instructor. While this seldom occurs before three hours have elapsed, this grueling session is made more pleasant by a 15-minute break during which a snack of some type, pro-

vided by either a student or the instructor, is available.

Seminars are offered in all of the standard upper-level subjects of the undergraduate physics and astronomy curriculum. The textbooks and the amount of material covered are typical of lecture courses at other institutions. While it is certainly true that some students find the seminar format more conducive to their style of learning than do others, history has demonstrated that all Swarthmore students can succeed with the approach if they are willing to devote the necessary time and energy. Some can go off on their own between seminar meetings and learn effectively. Others must work extensively with other seminar students and the instructor to be prepared for the next seminar meeting. Even more so than in lecture courses, the instructor must identify those students who are not keeping up and take steps to correct the situation. In all cases, we hope, the students gain an appreciation of what it takes to understand scientific concepts, what their own strengths and weaknesses are and how they can use various techniques and resources to aid their learning.

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GREENSTEIN REPLIES: Each of the above letters describes an additional nonstandard strategy, above and beyond those I described in my Opinion column, for effectively teaching science. Peter J. Collings discusses how the seminar has been used at Swarthmore College as an alternative format in a traditional "bread and butter" course, such that students work their way through the material in a textbook on their own rather than in a lecture environment. Ivan Semeniuk, in turn, emphasizes repeatedly the role of the innovative design of experiments in the conduct of science: What more exciting way to teach a subject than to present students with a scientific issue and then ask them to design for themselves an experiment by which it may be probed, rather than presenting them with one already assembled and merely asking them to passively take the data? And Elliot H. Weinberg emphasizes that all students, nonscience and science majors alike, invariably bring to the classroom various personal experiences—bungee jumping, scuba diving—that can be used to motivate the study of important physical principles.

I would argue that the distinction between the lecture and the seminar format is too narrow to do justice to the full range of strategies we are dis-

cussing here. I'd vote to term this kind of learning *active learning*, to distinguish it from the more passive learning of the traditional lecture course. These letters testify that active learning is a multifaceted affair and that it has a role throughout all science education.

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'Critical' Thinking *re* the Nervous System

John J. Hopfield writes in "Neurons, Dynamics and Computation" (February 1994, page 40): "The phenomena displayed by coupled integrate-and-fire neurons will be richer when the synaptic connection patterns are more complex. Even the replacement of equal all-to-all coupling by a fixed near-neighbor synaptic coupling in two dimensions . . . greatly changes the kinds of behavior that are found. This problem, which does not seem to have been studied in neurobiology, has in a limiting case a very close parallel with the Burridge-Knopoff model of earthquake generation at a junction between tectonic plates. (This point was jointly understood in discussions last spring between Andreas Herz, John Rundle and me.) . . . The slipping [in that model] is 'self-organized' and produces a power-law distribution of earthquake magnitudes." With respect to the term "self-organized," Hopfield cites 1989 work by Per Bak and Chao Tang.

In a 1979 paper¹ I compared the nervous system with a physical system near a critical point. What I then called "the principle of critical development in a nervous system" is related to what is now called "self-organized criticality." I discuss this principle in neurobiology further in my 1992 article "Target of Brain Activity: Its Own Critical Point."² The 2nd Appalachian Conference on Behavioral Neurodynamics (see reference 3), attended by Ilya Prigogine and by Bak, devoted several sessions to self-organization on 3–6 October 1993.

References

1. C. J. A. Game, Proc. Aust. Soc. Biophys. **3**, 15 (1979).
2. C. J. A. Game, Clin. Neurol. Neurosurg. **94** (Suppl.), S78 (1992).
3. C. J. A. Game, in *Origins: Brain and Self-Organization*, K.H. Pribram, ed., Lawrence Erlbaum, Hillsdale, N. J. (1994), p. 196.

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HOPFIELD REPLIES: What distinguishes physics from more philosophical forms of discourse, or from

mere analogizing, is the casting of discussions in terms of measurables and mathematics, so that statements can be tested by laboratory or computer experiments. The "criticality" of the nervous system discussed by Christopher J. A. Game in his referenced publications is not described in such terms.

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Medical Physics Jobs: What's the Prognosis?

Medical physics can be one of the most challenging and rewarding applications of physics in society today (as evidenced, for example, by Arthur Robinson's Career Choices column in *PHYSICS TODAY*, September 1993, page 47). The American Association of Physicists in Medicine, the largest professional organization of medical physicists, has over 3500 members worldwide. The majority of AAPM members practice in the United States. Unlike what we are seeing in other physics fields, there is still a shortage of medical physicists in North America, and this should remain the case at least into the near future. Below is an analysis of current employment prospects to provide useful information for anyone contemplating a medical physics career.

The medical physics profession is split into six major subspecialties: radiation therapy physics, diagnostic imaging physics, magnetic resonance imaging physics, radiation safety and health physics, nuclear medicine physics, and other applications of physics in medicine, for example, hyperthermia and photodynamic therapy. A career in any one of these specialties can be very fulfilling and will most likely offer a relatively high salary at this time. I myself have recently finished my PhD in medical physics at the University of Wisconsin and currently enjoy work in a hospital-based radiation therapy clinic as a clinical physicist.

Ideally one's own interest would be the most important driving force in choosing a specialty; however, more mundane factors should also be considered, such as the probability of finding a job quickly after finishing one's studies. This probability varies with specialty. The report of the most recent AAPM professional information survey¹ (data for 1993) shows that 68% of respondents claimed radiation therapy to be their primary involvement, 13% claimed diagnostic imaging, 4% magnetic resonance imaging, 7% radiation safety and 4% nuclear medicine; 4% were employed in

other categories. (Approximately three-quarters of the 2500 eligible medical physicists responded to the survey. The remaining 1000 members of the AAPM were either student, emeritus or charter members and were not included.) This survey alone may not give an accurate indication of hiring trends. If, for example, all available positions in a specialty were already filled, a high employment proportion in that specialty would incorrectly imply many employment opportunities. Similarly, a low employment proportion in any one specialty could be the result of there being either many vacancies or not many positions to begin with. To gain a better understanding of medical physics employment opportunities, it is therefore useful to analyze hiring trends over the past several years.

The AAPM operates a placement service for its members and every month publishes and distributes the "blue book," which lists vacant medical physics positions worldwide. Over the past three years² a total of 979 jobs were advertised. Most jobs were listed only once, with a high proportion being newly created positions. It is encouraging to see the high number of vacant positions posted monthly, although the average number of posts per month has decreased from a high of 34 in 1992 to only 20 in 1994, suggesting that the medical physics field is slowly saturating. Not surprisingly, radiation therapy physics represented the largest fraction, with well over half of all posted jobs in the past three years being in this specialty. Approximately 12% of all jobs were in diagnostic imaging, while the remaining groups each made up less than 10% of the total. The similarity of these figures to the employment breakdown described above suggests that the need for physicists in each subgroup remains constant.

References

1. *Professional Information Survey Report*, Am. Assoc. of Physicists in Medicine, New York (1993).
2. *AAPM Placement Service Bulletin*, Am. Assoc. of Physicists in Medicine, New York (January 1992 to December 1994).

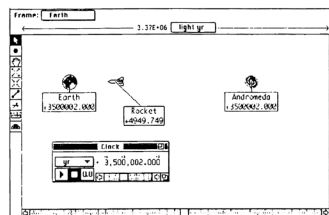
MATTHEW B. PODGORSK
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The Persian Pursuit of Physics

I recently went to Iran to attend the meeting of the Physical Society of Iran, which took place at the University of Kurdistan, in Kurdistan province, from 25 to 29 August. This annual conference, held in a different

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