

Perspectives on Atomic-Force Microscopy Education

Nancy A. Burnham¹

¹ Departments of Physics and Biomedical Engineering, Worcester Polytechnic Institute, Worcester MA

Based on the author's fifteen years of experience in education in atomic-force microscopy (AFM), current trends in AFM education will be summarized, challenges identified, and resources and recommendations given to people wishing to start their own AFM educational program [1-3].

Atomic-force microscopy (AFM) provides a window into the nano-world. Its principle of operation – a sharp tip on a flexible beam that is raster-scanned over a surface – is simple to understand. This simplicity, along with the size scales involved, can appeal to scientists both young and old.

As part of their degree requirements at Worcester Polytechnic Institute, two undergraduates researched what educators are doing to expose scientists and engineers to AFM [1]. They found that exposure to AFM has worked its way into grade schools and high schools, usually in the form of demonstrations with an actual AFM or with a macro-scale equivalent to show its operational principle. At the undergraduate level, if AFM is covered as a topic, it is usually restricted to one or a few laboratory exercises. In some cases, it is the topic of a full course [2]. At the graduate level, it has been given as a full course [2] or as an intensive short course during the summer [3]. Professionals typically attend short courses. Naturally, from the undergraduate to professional levels, one-on-one instruction is also common.

After researching the ways in which AFM education is being delivered, the students created a resource webpage [4] and a survey to send to the educators. Table I lists the principle questions that were asked in the survey. The main hurdles that the educators faced were the cost of the equipment and consumables, proper educational tools and materials, teaching time for instructors, and time for students to learn theory. They generally did not have any hesitations about creating an AFM lab or course because the benefits to the students are so great.

Concerning advice to prospective educators, the current educators advocate patience; there are many things that can and will go wrong. They also suggest a balance between theory and experiment, as well as trying to decrease overall cost by purchasing a teaching-oriented AFM that is less expensive and more robust than a research instrument. One can also decrease cost to the institution by writing proposals to funding agencies.

The answers to the question about if and how exposure to AFM benefits students were a resounding “yes!” The respondents mentioned its widespread adoption by industry and research, as well as its value in physics and materials science. Furthermore, many educators thought that AFM skills gave their students an edge in competing for jobs or placement in graduate school. Moreover, educators saw how many of the concepts discussed dryly in classrooms came to life for the students as they applied them in an AFM lab. In contrast, the respondents did not agree on the future of AFM education. Some did not view AFM as special, instead, that it is one of many techniques that students should learn. Others thought that as AFMs become more robust and less expensive, more students will be exposed to them, and the future is bright for AFM education.

Overall, the survey can be used as a resource for prospective educators as they talk to their administrators about the feasibility of AFM education at their own institutions. There is general agreement among current AFM educators that while the main challenge is the cost, the benefits to students make the effort worthwhile.

Table I. Questions asked of AFM educators in the survey.

What hurdles did you have to overcome in teaching Atomic Force Microscopy (e.g. cost of AFMs or consumables)? Do any remain?
Did you have any hesitations about creating an AFM lab or course? If so, what were they? Are they now assuaged?
What is your advice to prospective AFM educators?
Do you believe exposure to AFM benefits students? Why?
Do you see a future where AFM becomes more prevalent throughout all levels of education? Why or why not?

The author has developed educational materials for her AFM courses for undergraduates and graduate students. The principal one is a YouTube channel, AtomicForceMicro [5], at which thirty lessons in two playlists cover the basics of instrumentation and interpretation. A third playlist includes previews of the six lab experiments, along with some example mini-projects. And the fourth playlist encompasses “minute monologues” on research that has been performed in the author’s lab using AFM. Other materials, such as lab instructions, are available upon request. The author asks merely that her work be cited if readers adopt the materials. A textbook is planned that will tie all of the materials together.

The author’s development of the courses has been a great source of satisfaction. Nearly half of her students have gone on to use AFM in their education or in their careers. Others have written back years later to thank her for exposing them to the nano-world. The author’s dream is to see AFM education more widely available.

References:

- [1] “Atomic Force Microscopy Education” A.C. Pic, V.A. Moore and N.A. Burnham, in Global Perspectives on Nanoscience and Engineering Education, K. Winkelmann and B. Bhushan, eds., pp.131-69 (2016).
- [2] “Outcomes of and materials for two university-level courses on atomic force microscopy,” N.A. Burnham, *J. Nano Educ.* 5, 109-114 (2013), doi: 10.1166/jne.2013.1052.
- [3] “An Intensive Short Course on Atomic-Force Microscopy” Nancy A. Burnham, Andrea Arcifa, Mohammad Divandari, Christian Mathis, Shivaprakash N. Ramakrishna, and Nicholas D. Spencer, 2015 Conference on Laboratory Instruction Beyond the First Year of College Proceedings, pp. 24-27 (peer-reviewed) doi:10.1119/bfy.2015.pr.006.
- [4] Nano-Education Resources, Worcester Polytechnic Institute, created summer 2015, https://web.wpi.edu/academics/physics/AFM/nanoed_resources.html
- [5] AtomicForceMicro at You Tube, created March 2013, <https://www.youtube.com/user/AtomicForceMicro>
- [6] The Physics Department of Worcester Polytechnic Institute is gratefully acknowledged for its support of AFM education.