

Exposure to real data with all its imperfections and shortcomings and the experience of acquiring data through the students' own efforts are very hard lessons initially. Unlike the laboratory where a poor set of measurements may be retrieved and unlike the predigested data sets of textbooks, the students must make something of the data presented to them in the project situation and actually acquire, calibrate and reduce data in a practical class. In the case of the project they must look for sources of error which may weaken any conclusions to be drawn. In the case of observational experiments, they are aware that because of the vagaries of the weather, this chance may be the only chance to get a data set. A few students will be defeated by both situations in a way that they would not be troubled by a laboratory or lecture class. Most students come to terms with the project and observational class and it is one of the pleasures of such teaching to see judgement and confidence grow. Some students develop judgement and confidence to professional levels and it is interesting to note that such students are not necessarily those marked out as able by normal examination assessment procedures. It is this final group that are the most rewarding to teach.

McNally, D. 1990, "The Role of Projects in Astronomy Education" in *The Teaching of Astronomy* (Eds. Pasachoff and Percy), IAU Colloquium 105, Cambridge University Press, pp. 109-119.

ASTRONOMY RESEARCH PROJECTS FOR HIGH SCHOOL STUDENTS

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The excitement of research and discovery is a strong motivation and benefit in both doing and teaching science. The so-called "discovery approach", in which students discover (well-known) scientific concepts for themselves, is an essential aspect of good science teaching. The present paper, however, deals with situations in which high school students carry out *original* research, and thus derive the extra satisfaction of contributing to scientific knowledge.

This "hands-on" approach to astronomy education is not new. The University of Edinburgh has produced and distributed teaching packages of research-grade materials for many years. The growing education budget of the US National Science Foundation (NSF) has spurred the development of hands-on material in the US in the last decade (Pennypacker 1990).

Some original research projects can be carried out in a classroom setting, and high school teacher Jeff Lockwood (1993) has described his extensive experience in this area. He lists several research-based projects which have been carried out in the US, primarily through NSF funding. These include: CIPE, the Center for Image Processing in Education, and the Image Processing Program, both based at the

University of Arizona, and using CD-ROM archival images from spacecraft such as *Magellan* and *Voyager*; the Remote Access Astronomy Project, based at University of California Santa Barbara, which downloads images directly from a central archive; Hands-On Universe, based at Lawrence Berkeley Laboratories, which enables classes to "order" images from a remote 1.5 m telescope.

Variable stars are particularly well suited to student research projects (Percy 1990), and Janet Mattei and I are directing "Hands-On Astrophysics", a project based on the American Association of Variable Star Observers' unique international electronic database of variable star observations. Students experience the excitement of doing real science with real data, while developing and integrating skills in math, science and computing. Materials from this and other NSF-funded projects will soon be available to astronomy teachers worldwide.

A second approach to high school research projects is through individual mentoring by astronomers. The triennial national reports of IAU Commission 46 suggest that this occurs on an *ad hoc* basis in many countries, and Lockwood (1993) refers to some examples in the US. The University of Toronto has a particularly well-established mentorship program (Percy 1990) which enables outstanding senior high school students to work on research projects with faculty in many departments, not just in the sciences. To the student, the program offers challenge, skills development, and experience. To the mentor, it offers an enthusiastic, highly-capable assistant. It can also offer a useful link between the school and the university. Students frequently give presentations on their project to their class, or host visits by their mentor to their school.

Lockwood, J. 1993, *Mercury* 22, #2, 56.

Pennypacker, C. (editor) 1992, *Hands-On Astronomy for Education* (World Scientific, Singapore).

Percy, J.R. 1990, *JRASC* 84, 49.