From Curanderas to Gas Chromatography

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Medicinal Plants

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The Medicinal Plants of the Southwest summer workshop is an inquiry-based learning approach to increase interest and skills in biomedical research. Working in teams, Hispanic and Native American students discover the chemical and biological basis for the medicinal activity of regional plants used by healers.

The Medicinal Plants of the Southwest summer workshop is an inquiry-based learning approach to increasing students' interest and skills in biomedical research. Funded by the National Institutes of Health, our primary goal is to recruit ethnic minority students to graduate study, and ultimately to biomedical research careers. Participants are undergraduates, including high school graduates entering the university in the fall. Selection is based on GPA and essay statements on one of three topics.

The workshops objectives are to:

- provide students the opportunity to design and execute experiments in biomedical research,
- encourage the development of technical skills and knowledge in scientific fields, and
- raise ethnic minority students' awareness of the breadth of career opportunities in biomedical research.

A secondary goal of the workshop is to strengthen students' scientific life skills (i.e., oral and written communication, teamwork, and confidence with analytical instrumentation).

Participants characterize the chemical composition of regional plants and conduct bioassays screening for antimicrobial activity. These research experiences reinforce scientific concepts taught in chemistry and biology courses. For example, students prepare plant extracts using water, methanol, or hexane as solvents. This activity demonstrates many chemical principles, such as solubility and po-

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larity. Students compare the chemical composition of greenhouse-grown versus field-grown plants. These results demonstrate environmental influences on form and function in living organisms. Not only do students learn while they participate in the project but also they contribute new information and publish their results online at *http://medplant.nmsu.edu*.

Ethnobotany has great biomedical importance, and more importantly is very exciting to minority students. Medicinal plants were historically the sources of many of the chemistries in modern drugs, and there has been a recent surge in public interest in herbal medicines. In New Mexico, the Hispanic community and the different Native American tribes use herbal medicines derived from plants native to the southwest to augment the medicines they obtain from pharmacies. Many students volunteer information about their family's experience using a particular plant to treat an ailment. In many cases, students want to research a particular plant because of personal experience. Spurlin (1997) described a similar culturally relevant approach to science education.

Learning in Teams

The project attracts two types of students—those already interested in biomedical research careers and those interested in medicinal plants but who have never considered a biomedical career. We build teams composed of both types of students, and we try to combine those with different technical skills and backgrounds. More than 17 faculty from eight different academic units at New Mexico State University have participated as instructors or discussion leaders over the past four years. In any one summer, only four or five of these individuals are called upon.

Physicians, herbalists, *curanderas* (healers), storytellers, and scientists from the community and other universities also participate as discussion leaders or workshop speakers. There is a diverse, interdisciplinary climate in the workshop, with specific emphasis on multiple ways to learning mirrored by multiple experimental approaches to confirm data and ideas.

A typical schedule for a workshop is presented in Table 1. The participant teams assemble on the first day of the workshop. An ideal team has three members, each of whom has a different learning style, technical background, and degree of training. On the first day, we conduct a session on team building and assessment of learning styles. Students distribute 10 points by self-evaluating their chemistry, anthropology, computer science, and plant sciences skills. An Excel file of this data is used to sort the students into balanced groups; age and gender also influence team composition. Throughout the workshop, we remind participants to pay attention to their team's organization and to use the team members' strengths effectively. Within the first two days of the workshop, each team chooses a plant to characterize and a topic to research for the web report.

The workshop is designed to provide workplace training for students. They execute research tasks in these training sessions, which are often held in the morning, followed by an afternoon session to perform the research tasks. This model persists throughout the workshop schedule. The emphasis in the first week is on web-authoring techniques, plant sciences, and anthropology to support the execution of the literature research and the collection and harvesting of plant organs for chemical composition. Later in the workshop, the training focuses on chemical principles to support the research on plant extraction and analysis of chemical constituents. Finally, the training focuses on biological principles to support the research on bioassays screening for antimicrobial activities. Sample lesson plans for the chemistry labs are published on our website (available at *http://medplant.nmsu.edu*) under Program Goals.

Every week of the workshop, we facilitate a discussion on scientific research and the ethical implications of research. For example, students read the Belmont report (Anonymous 1979) and then discuss the social and ethical implications of human subjects in biomedical research. Students also read articles on international ethnobotanical projects (Shiva and Holla-Bhar 1996) and then discuss the social and ethical implications of biopiracy.

Hazardous chemicals and biologically hazardous materials are used in this research. During the workshop,

TABLE 1

Summer workshop schedule.

Week	Morning	Afternoon
1	Introduction History of medicinal plants Plant anatomy	Organize teams Learning assistance self-testing Literature research—library and internet
2	Safety issues Chemical extractions Selection of solvents	Design experiments Harvest plant material Perform extractions
3	Analytical instrumentation	Run separations and analyses Publish literature research on web
4	Chemical structures	Refine extractions—repeat selected extractions and analyses
5	Biochemistry of plant second products Microbiology	Design and set up bio-assays Conduct bioassays
6	Human biology	Continue bioassays
7	Statistical analyses of data Biological databases	Write up results Populate database Propose plants for future study Critique workshop

the university safety office staff provides a special session on chemical hygiene. Each protocol for chemical extraction or bioassay is preceded by oral and written instruction in the specific safety issues associated with that protocol. All participants are provided with safety glasses, lab coats, scrub pants, and foot coverings.

Learning by Doing

Each team develops an experiment to conduct during the workshop. For example, some teams determine if the environment influences the chemical composition of medicinal plants. They collect above-ground organs, leaves, stems, flowers, or fruit from plants cultured under different conditions (i.e., in a greenhouse versus within the campus landscape versus in an unmanaged area of campus property). This requires students to accurately identify the target plant in the field. The organs are extracted with one or two different solvents, and team members use the chromatograms from the gas chromatogram/mass spectrometer (GC/MS) to determine if there are qualitative and/or quantitative differences in the extract profiles.

Other teams design experiments to determine if different organs of medicinal plants accumulate different bioactive compounds. They extract roots, leaves, stems, and so forth with different solvents. They then inspect GC/MS chromatograms to determine if the chemical compositions of the organs are different. These results are compared with ethnobotanical information on which parts of the plant are used by healers.

Results across teams are also analyzed at the end of the workshop. Each team reports their results, and between-group conclusions about efficiencies of different extraction protocols, bioassay results, and the effect of environment are discussed. Graduate students and faculty give the participants guidelines on the specific details of the chemical extraction methods, amounts and type of plant material to use, and volumes and natures of solvents. Students prepare samples for these analyses and interpret the results in consultations with the faculty and graduate students.

As teams, participants are required to produce two different written reports. The first, due about midway through the summer workshop, is a review of the literature on either a medicinal plant or a medical condition treated by plants. These reports are written as web documents and are published on the website. Students develop artwork and photos and write text summarizing the information they have obtained from their literature review. Students have published web reports on more than 30 species across 21 families and on six diseases commonly treated with plants (see the Plants and Diseases web pages, which can be found online at *http://medplant.nmsu.edu*).

The second written report, due on the last day of the workshop, is a write-up of the methods and results of the chemical and biological studies each team has performed. These are written in the style of a journal article, with an introduction, materials-and-methods section, and (usually) a combined results and discussion section. These reports include the results of the chemical extractions and compositional analyses as well as the bioassays. Typically, these reports will include representative GC/MS chromatograms, tables of abundances of compounds, and tables of antibacterial effects of different extracts.

TABLE 2

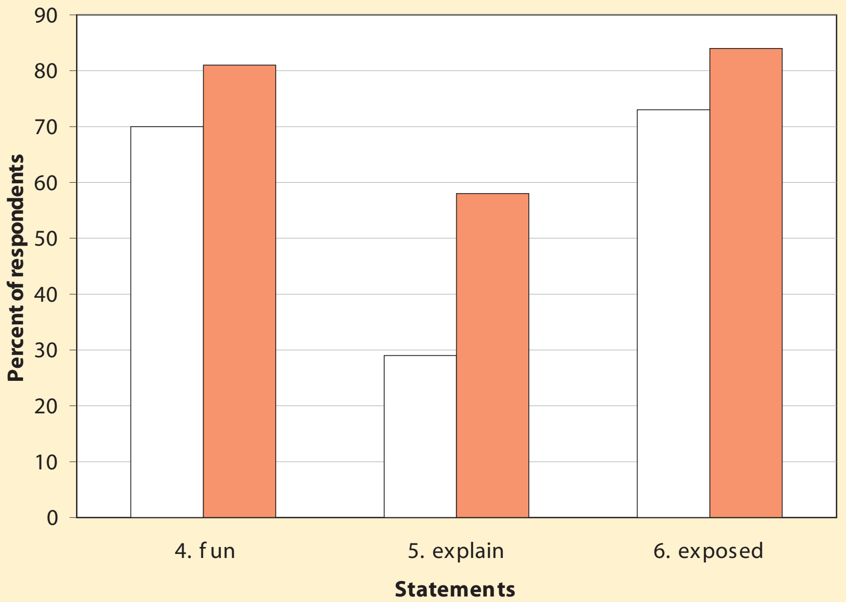
Summary of summer medicinal plant workshops.

Year	Duration (weeks)	Total students	Gender M	Gender F	Ethnicity[1] H	Ethnicity[1] A	Ethnicity[1] N	Ethnicity[1] O	Plants extracted	Number of web reports[2]
2000	4	12	2	10	8	2	1	1	*Anemopsis californica*	4
2001	8	36	16	20	10	1	19	6	*Levisticum officinale* *Penstemon superbus* *P. pseduospectablis* *Salvia apiana* *Sphaeralcea lobata* *Verbascum thapsus* *Verbena rigida*	13
2002	6	25	6	19	12	1	4	8	*Cercocarpus montanus* *Cucurbita foetidissima* *Ephedra spp.* *Larrea tridentata* *Lobelia cardinalis*	9
2003	6	20	3	17	14	1	2	3	*Juniperus monosperma* *Larrea tridentata* *Lavandula officinalis* *Perovskia atriplicifolia* *Prosopis spp.* *Rosmarinus officinalis*	6
Total		93	27	66	44	5	26	18		32

[1]Ethnicity: Hispanic (H); African-American (A); Native-American (N); Other (O).
[2]*http://medplant.nmsu.edu*

FIGURE 1

Percentage of workshop participants who agreed or strongly agreed with the statements numbered as in Table 3; open bars = pre-workshop values; filled bars = post-workshop values.



Workshop Analysis

There are two sources of information for the workshop analysis. The first is the group of students; their impressions of the workshop are captured in survey tools, described below. The second source is the staff, graduate students, and faculty who facilitated the workshop. In an oral debriefing, they give their impressions immediately after the last session with the students. Using both types of information, we will revise the workshop instruction plan, schedule, and topics for future offerings of this course.

To determine the program's effect on students' interest in biomedical research careers, we have used several different surveys to monitor the numbers and attitudes of students who continue to actively participate in research programs. Research opportunities on the campus for participants of the summer workshop include student employment as well as NIH-, NSF-, and DOE-funded programs; students can perform biomedical research activities in faculty-mentored labs.

We use three types of surveys to monitor students' attitudes. On the first and last days of the workshop, students answer a survey on their attitudes toward science and biomedical research careers and their degree of preparation and confidence in taking science classes. Using student-generated code names, anonymous pre- and post-course surveys are paired to determine the program's effect on individual students' attitudes and on the students in aggregate. Participants fill out a third survey one year after the workshop to measure their perception of the workshop's effect on academic performance in science classes.

We have conducted four summer workshops, one in each of the summers since 2000 (Table 2). We have varied the size of the workshop from 12 to 36 participants and the duration from 4 to 8 weeks. For our campus and physical resources, we consider the optimal workshop structure to be 6 to 7 weeks in duration for 20 to 24 participants. The majority of workshop participants have been Hispanic, with underrepresented minorities comprising 81% of the participants. Substantially more than half of the participants have been women (70%).

We have been successful in stimulating students' interest in biomedical research. From the first three workshops, 59% (43 out of 73) students have continued on in biomedical research. We consider this degree of student retention in biomedical research to be a good indi-

TABLE 3

Comparison of paired pre- and post-workshop responses.

Means on a scale of 1 to 5, where 1 = strongly disagree and 5 = strongly agree. (Significant differences ** 95% confidence.)

	Statement	Mean pre	Mean post	N
1.	Taking science courses now will be useful in my future career.	4.57	4.64	69
2.	I find science to be very logical and clear.	3.88	4.01	69
3.	The thought of taking another science course makes me feel sick.	1.77	1.74	69
4.	I think science is fun.	4.01	4.37**	68
5.	I find it easy to explain a scientific topic to someone else.	3.33	3.61**	79
6.	I have been exposed to scientific procedure, theory, and studies.	3.99	4.40**	68
7.	I am afraid of science.	1.99	1.84	69
8.	I would like to learn more science.	4.51	4.54	69
9.	I feel confident about my ability to learn and understand science.	4.07	4.17	69
10.	I think science courses are difficult.	3.16	2.96	69
11.	I think that participating in the Medicinal Plants of the Southwest workshop will help me with my coursework.	4.51	4.49	68

TABLE 4

Follow-up survey responses.

Percent of respondents who agreed or strongly agreed with the following statements (30 respondents to mailed survey).

Statement	Frequency
The workshop gave me an advantage when learning chemistry, biology, or other sciences.	77%
The workshop positively influenced my attitudes about biomedical careers.	77%
The workshop increased my understanding and ability to use analytical instruments.	73%
The workshop helped improve my ability to communicate scientifically.	73%
The workshop helped to improve my team working skills.	70%
The material covered in the workshop helped me with my chemistry classes.	65%
The material covered in the workshop helped me with my biology classes.	63%
The workshop changed the way I study and learn scientific material.	57%
The workshop helped to improve my computer skills.	46%

cator of the effect of this program. Kahle (1982) identified minority students as field-dependent learners, or group learners. Wiens et al. (2003) interpreted gender differences among biology majors as also being related to this learning style difference. Several organizational elements of the workshop may be more suited to field-dependent learners. The emphasis on teamwork, as well as participants' opportunity to repeat and refine experiments and methods, may have contributed to the program's success in retaining female and minority students in research paths.

Based on the paired pre- and post-workshop surveys, we know that the workshop greatly influenced students' attitudes. The average post-workshop attitude monitored by agreement with statements 4, 5, and 6 in Table 3 was quite a bit different than the pre-workshop value. Our survey tools were different in 2000; the data in Table 3 represent the years 2001 to 2003 participants except for statement 5, which includes year 2000 responses.

In national surveys, 47% of 12th graders agree with the statement, "I like science"; fewer (39%) agree with the statement "I am good at science" (Anonymous 2003). Fewer females (42%) and Hispanics (41%) like science than the general population of 12th graders, and the percentages who think they are good at science are equally lower (34% of 12th-grade females and 26% of 12th-grade Hispanics). The majority of participants in the workshop are female Hispanics, older than 12th graders. Our pre-workshop participants had attitudes similar to the national 12th-grade population, and 54% thought science was fun. At the close of the workshop, the participants had greatly improved their positive attitudes about science (Figure 1, page 29).

We mailed a follow-up survey to all the participants in spring 2003. Thirty participants responded (out of 65, or 46%). Of those, 85% agreed that the workshop "created or maintained an interest in graduate school." Student perception of the workshop after at least one year of college course work is that they were better able to work in teams, communicate scientifically, and learn science coursework (Table 4). They did not agree that the workshop improved their computer skills or that the workshop changed how they studied scientific material.

In the paired pre- and post-workshop surveys, student attitudes did not change to indicate that the workshop would help them with their coursework; however, after they had spent a year or longer in courses, close to 80% of the respondents agreed that the workshop had helped them in their coursework. We are especially pleased by this improvement following real experiences in classrooms for these students. Using a regionally and culturally relevant theme—medicinal plants—to provide structured research experiences for our students appears to be an effective way to both motivate and maintain student interest in research careers. ■

Acknowledgments

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References

Anonymous. 1979. National Commission for the Protection of Human Subjects of Biomedical and Behavioral Research. *The Belmont Report, Ethical Principles and Guidelines for the Protection of Human Subjects of Research*. (April 18, 1979). Available online at *http://ohsr.od.nih.gov/mpa/belmont.php3*.

Anonymous. 2003. National Science Foundation, Division of Science Resources Statistics. *Women, Minorities and Persons with Disabilities in Science and Engineering: 2002*. NSF-03-312 (Arlington, VA 2003).

Kahle, J. B. 1982. The disadvantaged majority: Biology education for women and minorities. *The American Biology Teacher* 44 (6): 351–356.

Shiva, V., and R. Holla-Bhar. 1996. Piracy by patent, the case of the neem tree. In *The Case Against the Global Economy*. J. Mander and E. Goldsmith, (eds.). Sierra Club Books, San Francisco, pp. 146–159.

Spurlin, Q. 1997. Phytochemistry and culture: Connecting science to students' experiences. *Journal of College Science Teaching* 27 (1): 23–28.

Wiens, D. J., D. J. Depping, S. R. Wallerich, E. S. Van Laar, and A. L. Juhl. 2003. Gender matters, factors influencing biology interest among undergraduate majors. *Journal of College Science Teaching* 33 (1): 32–36.