Chemists and educators are concerned about how they can encourage and motivate students to pursue careers in chemistry. For more than 20 years, John P. Walters has been developing an innovative curriculum for students that emphasizes chemistry and, simultaneously, management and leadership skills (see Anal. Chem. 1991, 63, 347 A). In this first of a series of three REPORTs, Walters establishes the framework on which this curriculum is based. Part II, which will appear in the November 15 issue, describes the physical resources (lab space and equipment) necessary to undertake this approach. Part III, to be presented in the December 15 issue, discusses the actual written laboratory experiments and provides an evaluative summary of the role-playing approach.

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This series of three articles will describe a set of laboratory courses based on modern analytical chemistry (1, 2) that expand the conventional educational experience into interdependent, people-oriented, small-group learning. The courses focus on learning new chemistry while simultaneously developing management and leadership skills. These courses present analytical chemistry laboratories, as well as lectures, in a new way at the undergraduate, first-year graduate, and high school levels. The approach was first explored in 1962 in graduate courses at the University of Illinois-Urbana, moved into undergraduate courses in 1968 at the University of Wisconsin-Madison, and evolved to its present form at St. Olaf College in succeeding years.

The approach is different from traditional laboratory programs. The most obvious difference is that its central focus involves students serving in, or “playing,” various roles with differing responsibilities. I call this a “role-playing” laboratory. The more fundamental difference is that the approach is based on interdependent contributions to the integrated solution of problem-oriented experiments called “management dilemmas.” Skilled contributors rotate among several roles within a small group.

The role-playing laboratory appears to fit well into modern theories of constructivistic education (3), “non-zero-sum” gaming (4), and collaborative management focused on service and innovation (5), as well as the more central ethic of caring for others. Although it is noncompetitive in the zero-sum sense, it retains the...
spirit of deadline-based problem solving and thus encourages a high degree of innovation within the small groups. By rotation through the roles, everyone is included in the whole educational process, avoiding hierarchical exclusion and its attendant alienation.

Role-playing

What is role-playing? Role-playing, also known as "psychodrama," is the adoption and subsequent acting out of a deliberately exaggerated cultural stereotype. It is a technique, not a principle, and it is done to explore what it would be like, in professional life, to have any or all of the stereotype's actual properties. For example, if one wanted to know what it would be like to be a Ph.D.-level leader of a professional research group, then the role could be cast by someone familiar with the demands of that job and acted out in exaggerated form by novices who perhaps needed motivation to study to this end.

Role-playing is a legitimate teaching technique. It is to teaching what wire wrapping is to circuit building, what icons are to computer operation, and what group therapy is to psychology. Thus it can be used to teach any subject, ethic, or belief system: competitive or noncompetitive, peaceful or combative, group-oriented or individualistic. It is a very effective teaching technique, but its results are still dependent on the way in which educational principles are applied to the material at hand. Here, the educational principles came first; after many years of attempting to implement them in a technical context, role-playing has proven most effective. It is experiential, by definition.

Historically, the technique of role-playing has been successful in group therapy (6), counseling (7), technical theater (8), teaching language (9), creativity teaching (10), professional management (11), and community building (12). In the sciences, it has been used as the basis of a highly competitive and judgmental advanced physics lab (13) and for some exercises in chemistry (14-16). There are several good resources for its application to management training (17) and classroom teaching (18) that should be useful in other contexts as well.

From these references it is clear that one of the advantages of role-playing in the chemistry laboratory would be to allow development of technical expertise at an individual level while at the same time stressing and developing communication and collaborative skills. If the course is structured to include both of these objectives, then role-playing allows students to explore new self-images in a new context for new meaning, and it may illustrate for others what can happen in future situations that thrive on interdependent problem solving in small groups (19). It is particularly effective for teaching undergraduate analytical chemistry because much analytical work naturally thrives in an interdependent, diverse small group.

Educational principles

Role-playing, as used for laboratory structure, is applied to two fundamental educational principles. These principles have been distilled from many other possibilities and now form the core of the entire teaching effort.

The first principle is that all laboratory work involves interdependence between skilled individuals working in community, as opposed to competition between independent individuals working in isolation. The second is that all work is based on division of responsibilities, as opposed to division of labor. These principles are at the heart of all the experiments that have been written for the laboratories, all logistical structuring, and all aspects of the role-playing technique.

The practical emphasis in the lab is twofold: problem solving in small groups and endorsed, facile communication within and between groups. The members of the groups are encouraged to be interdependent (i.e., mutually dependent in the whole although individual in the moment). To facilitate this dichotomy, the experiment's objectives and problems are made sufficiently challenging that they are best solved by division of responsibility between people in the group.

The solution thus requires interdependence. Each person is responsible for a key piece of the solution, and the whole solution materializes only when the pieces are integrated, usually by consensus leadership. The motivation, therefore, is task orientation, and the task should be sufficiently captivating that those in the small group will want to "hit squad" that will "cllobber" the problem. The motivating reward is primarily to be able to solve another problem, and only secondarily to receive a good grade.

The interdependent integration needed for a solution is poorly done if communication between role-players occurs only after the work has commenced. If communication about the responsibilities assumed is established before the work commences and continues while it is going on, then the integration is easy and almost always successful. Thus proprietary isolation between group members is self-defeating and is usually recognized as such early on. Good communication enables independent efforts to coalesce frequently, and members of the group periodically come together to communicate, then break apart to react to the news.

The professor is no longer an authority figure (21) in this laboratory structure. In fact, the best visible role for the professor to play is that of paid consultant. The benefits of this role are well known (22). In one current application, the professor (me) is "paid" with food (apples) when asked to make accountable decisions. Interpretations, as opposed to decisions, are not billable. This scheme is just right to disestablish the authority role the professor's position often carries without harming its leadership credibility.

Obviously, the professor is not just a consultant; actually he or she creates the course standards as well as the written lab experiments. Here, the first sets of experiments are designed to give the group members freedom to create while still being guided within sensible limits. But,
Data from past efforts are available to the role-players before they start an experiment. (Part II will describe use of the course microcomputer.) These data are tapped for what they are worth. Communication between classes and students at other physical locations also is enabled and encouraged. The professor validates (or alternately prohibits) such collaboration. This is using authority, but the students do not need to be made aware of this while they are in the lab working. Instead, it becomes a diffuse “given” that sets the course “flavor.”

The students’ roles

Playing roles is unquestionably the most visible and distinctive feature of a running analytical laboratory session. Four roles are described for groups of four students, and each role embodies different functions and cultural stereotyping patterned after the way analytical chemistry is practiced in research, clinical, and industrial environments.

Each group of four students is called a company. Four companies form a lab section, and multiple sections constitute a course. The four roles are all played within each company. The name “company” does not necessarily imply a parallel to an industrial organization. In fact, the methods used in this course are not always followed in industrial organizations (see Reference 2). It is, instead, a more comfortable name for students to use than “community,” which it formally represents.

Four roles are played individually; each person has one role in the company. Rotation between roles is built into the laboratory schedule so that each person plays each role at least once (and preferably twice) in the semester. A diagrammatic example of this for four experiments is shown in Figure 1. The rotation is a fundamental feature of this lab.

The four roles adopted in each company are Manager, Chemist, Hardware, and Software. The name of the role is adopted by the person playing it as an alternative to his or her own name, others in the company can refer to irregularities and problems in the role as it is played, without referring by name to the person playing it. Small-group dynamics are better served, and there is less transfer of any lab problems outside the immediate lab environment. Adventure is added to most discussions, and people are more willing to interact.

The names of the roles are chosen to suggest how responsibility should be divided between members of the company in the execution of the experiment. There is no parallel to this in the more simple, and less effective, division of labor that accompanies the common “partners” approach. Each role carries general responsibilities that exist regardless of the specific experiment being done, as well as some that are experiment specific. Descriptions of these general responsibilities follow.

- Manager is responsible for the organization, implementation, outcome, and reporting of the results of the experiment. Manager prepares all information for reporting and actually sends it (usually via electronic mail) to the person or persons to whom the company is responsible. Manager is responsible for the quality of communication between people playing out the other roles. Manager has the “management interview” and gets the grade for the entire effort. All others in the company get the same grade as Manager.
- Chemist is responsible for the preparation, blending, and delivery, in the right place and time and in the right chemical form, of all the reagents and analytical standards needed to implement Manager’s plan of execution for the experiment.
- Hardware is responsible for the assembly and operation of all of the instrumentation needed to implement Manager’s plan of execution of the experiment.
- Software is responsible for the creation, linking, or operation of any software that Manager, Chemist, or Hardware need to make Manager’s plan of execution work. Software is also responsible for telecommunications programs used for file transfer.

Manager is the one role that requires additional outside reading for most of the students approaching it for the first time. To this end, four popular books are available to the person who will play Manager. They are best read (and perhaps cover to cover) two to three weeks before Manager’s rotation begins.

Courses

The roles above are introduced and implemented in three lecture/lab courses (Figure 2). The two upper-level courses, Analytical Chemistry and Instrumental Analysis, are preceded by an introductory course, Uses of Computers in the Health-Related Professions. This course is a one-month intensive “interim” session. It helps develop a satisfactory level of computer literacy in the information transfer skills that will be needed in the upper-level laboratories and is targeted at a broad range of interests and prior perspectives.

Not every student who takes the upper-level laboratory courses will be enrolled in this interim course. Those who take the course later can help, however, by acting as enthusiastic consultants for those who are not well grounded in computer use at the start of the other analytical courses.

The introductory computing course also helps in the development of the other role-playing laboratories by serving as a software development

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test site. Most new software developments are implemented here before showing up in either of the upper-level laboratories. The title and format of this course reflect an inherent interest, and the experiments used in it are designed to be naturally captivating and topically stimulating.

Thus the computer can be first presented in a positive and intriguing manner as a useful and important information-handling device, rather than as an autocratic training device requiring detailed programming skills and complete mastery of logical thinking.

The Analytical Chemistry (junior-level) course is the largest of the three. Enrollments in this course at St. Olaf have ranged from eight to 85 over the past nine years. It has a “production quality control” flavor, by deliberate design, and receives its experiments in more or less finished form from the work of students who have previously taken the Instrumental Analysis (senior-level) course. In fact, the declared intent of the senior laboratory is that of “methods development of experiments” for the junior course. Experiments for the junior course are the product of the senior course, giving it a decided service emphasis. The actual quality of the QC experiments is in turn a positive driving force for better methods development in the senior course.

This latter emphasis gives the Instrumental Analysis laboratory a much-needed teaching structure. When analytical “methods development” is the central lab guideline, there is no longer the quandary as to whether to teach the instrument ("using toys") or teach the method ("button pushing") (26). Instead, a mature blend of methodology and detailed instrumentation is explored with an eye to its eventual adoption as an experiment by people ("customers") who themselves will be at the same level as the developers were one year before. Good incentive results.

The emphasis given to the roles in the junior and senior courses varies. This emphasis is communicated in both the written material and the verbal instructional tone of lectures and other meetings. For example, in the junior course the emphasis given to the tasks that Manager performs is primarily organization. In the senior course the emphasis in the same role is more on design. This reflects the differences in the two courses. Figure 2 summarizes these role emphases.

Software plays a critical role in both courses because the entire role-playing experiment focuses on communication of instrumental, technical, and textual information. The emphasis for this role in the junior course is the collection of information; in the senior course it is extended to analysis of information. In both courses the use of word processors, spreadsheets, and flat databases is the clear feature of the role. This role encompasses the beginnings, though modest, of computer-based laboratory information management (27).

Motives

The primary reason for beginning a role-playing, small-group lab activity in the analytical curriculum was to enhance the degree to which students “own” the results of their lab work by interacting with one another. This ownership should then produce better transfer of knowledge within the initial learning context and lead students closer to the high-level goal of “synthesis” (28) and research-level discovery.

This motive of ownership was explored at the University of Wisconsin–Madison in undergraduate courses between 1968 and 1978. After 10 years of observation in the large analytical labs, it was clear that the more that one person taught another what he or she was doing, the more the “student” identified with the work done, the better the understanding was of what had been done and what was being taught, and the more he or she retained the material after the course.

At St. Olaf, the “partners” way of trying to achieve this interaction too often produced a dominant/dependent operating mode; it was not clear who was responsible for the results of the work and, consequently, who “owned” the experience and knowledge gained from it. Thus such knowledge remained compartmentalized in its initial context. Students moving into other courses and new learning situations appeared correspondingly deficient. A different vehicle was necessary to promote the division of responsibility and the clear ownership of the experience, and not simply the division of labor. The adoption of roles did this.

There is a general perception that both the lecture and the lab need to be modified to allow more discovery and more student participation in the discovery process. Pickering (29) stresses the need to move away from experiments that illustrate concepts by simple duplication of earlier, discovery-oriented thinking, and instead allow the students a more active decision-making role. Scheerer (30) carries similar reasoning into the lecture environment, stressing the importance of community.

The fact that role-playing adds more realism to the often dull analytical laboratory, which traditionally has stressed isolated, competitive motor-skill-based performance, pro-

Figure 2. Courses comprising the role-playing analytical curriculum and the responsibilities associated with the roles played.

The junior course is commonly referred to as Analytical Chemistry.
What do students think of this innovative curriculum? Analytical Chemistry spoke with current and former students of Professor Walters, whom they refer to as "Doc," and asked them to share their views of how the classes have affected them, their career plans, and their view of chemistry.

Maren K. Bunge holds a B.A. degree in chemistry from St. Olaf College (1991), where she was enrolled in Professor Walters' senior-level Instrumental Analysis class. She is employed by Braun Intertec, an environmental consulting firm in St. Paul, MN, where she is involved in trace organic analysis of water and waste samples.

Andrew D. Carlson is a 1991 graduate of St. Olaf College who completed both the junior- and sophomore-level classes (Analytical Chemistry and Computers in the Health Field) taught by Professor Walters. As a senior, he was a teaching assistant for junior-level Analytical Chemistry. He is currently a chemist in the bioanalytical chemistry department of the Analytical Development Division of Lilly Laboratories, where he is involved in the development of drug assays.

Paul T. Jackson is a senior chemistry major at St. Olaf College. He completed the junior-level Analytical Chemistry course and is currently enrolled in the senior-level Instrumental Analysis class.

Kevin Wickman graduated from St. Olaf College in 1991 with a chemistry major. He completed the senior-level Instrumental Analysis class. Currently, he is a graduate student in the neuroscience department at the Mayo Graduate School of Medicine (Rochester, MN).

**AC:** How did this class compare with others you have taken?

**Jackson:** The class is unique in its approach to students; both class lectures and labs are integrated into one network of information. Thus, a large demand is made on time, in the form of work, reading, and preparation.

**Wickman:** I don't remember my opinion of analytical chemistry before this course, but I left impressed by the tremendous amount of electronics, physics, and management that must and does accompany the chemistry being done.

**Carlson:** Initially, I thought they were involved with number crunching, electrochemistry, and instrumentation—stuff that I thought was boring. Through this class, my opinion has changed a lot.

**AC:** Did the class and your interaction with Professor Walters help you clarify your career goals?

**Carlson:** I took Doc's junior-level class and got a summer job in a small biotech firm because of the spreadsheet experience I gained in the class. I found that real-world chemistry is fun and that graduate and medical schools were not the only options open to me. Graduate school remains a possibility, but it's probably two to three years off, if at all. At present, I'd like to gain additional experience at Lilly beyond the lab, perhaps in marketing or management.

**Bunge:** In the laboratory, I was exposed to methods development, and this helped me decide that I'd like to pursue Ph.D.-level research. We were also exposed to various applications of analytical chemistry (e.g., bioanalytical, environmental), which further enhanced the process of choosing a career path. Before taking this class, I didn't think I'd enjoy a management position. My experience with role-playing, however, enhanced my confidence in my abilities and led to the realization that I'd really enjoy a management position.

**Wickman:** One conversation with Doc convinced me that I have to do state-of-the-art research. Other conversations centered on my psychological approach to such research. The class convinced me that I have the potential to succeed in such an arena. He is why I'm doing what I am doing today.

**Jackson:** I had been contemplating becoming a professor at a college or university when I became involved with Professor Walters and his course. Our discussions provided me with a realistic perception of what being a professor is like. They also fostered a desire to apply my new knowledge of analytical chemistry and incorporate it with my interest in organic synthesis.
vides another good reason for its introduction and use. Analytical laboratories often have suffered because of the assumption that it was enough to say that good techniques should be done well, without allowing students to blend techniques into methods where there is potential for complete failure (32).

Failing in a zero-sum competitive, skill-focused analytical laboratory resulted in demoralization and hostility more often than experiential wisdom for those who were not already talented in methodical manipulation. Role-playing in interdependent small groups, by contrast, encourages and allows an atmosphere in which students can make mistakes without the demoralizing effects of complete personal failure.

In a non-zero-sum situation (4), students can see what happens when seemingly small decisions about experiment design and laboratory technique combine in unexpectedly influential ways. Such is not a failure. Real growth can occur. The model at St. Olaf has been observed to increase the performance of the whole class and establish analytical work as a stimulating form of problem solving, while not disturbing those who naturally move to the top of any class. It is quality of life in the technical environment that is most improved for the ordinary student.

Role-playing in small groups endorses information sharing and interaction between skilled specialists as important reasons for doing technical work. The sharing of information adds to the excitement of addressing the target problem, and it binds the companies. The effect is real; technical quality improves decidedly with greater desire (endorsed by Upper Management, the professor) to communicate what has been seen. Data can readily be compared; spreadsheets and graphs can be displayed or telemetered between companies.

It appears that others (4, 5) are seeing that the interpersonal attitudes that we have while doing our work can influence our abilities to perform well, alone or communally, as much as the private anxiety we have about fear of failing in an authoritatively dominated classroom, examination, or lab instructional session can. The issue pivots around grading.

What about grading?
Grading in the role-playing lab effort is different. Traditional analytical schemes focusing mainly on synthetic unknowns and getting a statistically desirable answer ideally reflect the principle of “discrimination” (32) (i.e., careless efforts should produce lower grades). The experiment is designed best that best discriminates between good and poor students, statistically. Although not rejecting this principle as such, the role-playing, interdependent small-group model grades on the principle that good management produces good results.

Good grades do come from good results, but good results come from good management. Thus the results, per se, are not graded. Instead the management is.

How can “good management” be graded objectively? It depends on what Upper Management values and sets as objectives. If that value system is understood by the company Managers and the objectives of the experiment are actually met, then good management has been accomplished.

Management objectives and role responsibilities for the experiments are set by Upper Management and reflect conventional wisdom of the area, here analytical chemistry, as illustrated in modern textbooks for the area (e.g., 33, 34). These set the technical targets. The tone for their attack is set by direct example and a lot of “management by wandering around” by Upper Management during the lab sessions.

The more involved and well prepared the Manager, the better the objectives can be understood. Model data and reports from previous sessions of the same experiment are stored in a common Xenix-based course microcomputer, and the files can be read at any time, day or night. The shrewd Manager can motivate his or her Software person to download these data so that they can be studied as part of the preparation for the current experiment.

The old data do not fit exactly into the new context, but the fit is close enough that some creative adaptation will be considered. Suffice it to say that coming to the lab without a plan is not shrewd management, and the results are indeed predictable.

Although communication is often an overworked word, it still is true that good managers are also good at establishing open and assertive communication between the people they manage. When an interdependent effort is under way, good management assures that people know what every person’s problems, skills, and responsibilities are, so that their own efforts can be appropriately fit into the context of the problem and objectives. Good communication does not occur spontaneously. Good management (leadership) produces good communication.

The usage is purportedly what differentiates us from the lower pri-mates (35). A good lab education infers learning how to use tools. In the lab, this is not a hardware problem. Hardware, as a role, has to show skill in operating a tool, but the way in which it is used as part of the problem-solving mix is a management call. This can be graded, because the way a tool is used is a studied choice.

Consider the problem of an instrument that suddenly “breaks.” Did it matter? Whose fault is it? How could it have been anticipated? How could it have been prevented? What can be done about it if it happens? How can it be fixed? If the broken instrument cannot be fixed, how can its function be replaced for the moment? These are management, not hardware, problems that young people need to address before they are professionally employed. The creative Manager recognizes that a malfunctioning instrument is less a hardware problem than a management problem. He or she sees that any instrument, new or old, will have topical malfunctions to varying degrees as it is used.

Good management thus includes a plan of experiment execution with compensating paths that can be elected from short-term feedback of intermediate results, including setting up networks with other Managers for short-term loans and leases.

Discernment as a grading philosophy operates in the role-playing lab, but more as an effect than a cause. Good management is the cause, and it is graded. Good results are the effects, and they are celebrated.

Each Manager is told in writing before the experiment begins what values Upper Management prizes and is scheduled for a “management interview” during which he or she receives a grade (and thus the grade for everyone managed).

The management interview
Information for setting the grade comes from three sources. The actual lab data and interpreted results, as well as any spreadsheets used to work up the data, are sent to Upper Management via electronic mail. These do not actually constitute a “report” in the traditional sense, but instead comprise the electronic equivalent of the old “laboratory notebook.” These comprise the first
source of gradable information.

The second is a series of informal "inquiries" made of people while they are working on a problem to determine if they know what their fellow role-players are doing and, in the context of the experiment objectives, if they understand how their own responsibilities relate to the other roles. These inquiries are made informally by Upper Management, and a set of observations is made and communicated to Manager during or shortly after the lab session.

These two sources of information are available to Manager when he or she prepares a brief narrative summary of the effort that will be mailed to Upper Management before the management interview is held. This summary is the third source of gradable information. Little paper is expected or used; records are mostly electronic, as are narrative comments and interpretations, largely because electronic commentary can be read collectively ("watching TV") at the start of the interview.

The management interview is an informal discussion between Upper Management and Manager about the experimental session for which he or she was responsible. This is an interview; it is not an oral examination. The interview begins with a series of questions that are known to everyone in the lab from the start of the semester; they signal what Upper Management values at the "policy level" as management styles and goals, and they are put in writing in the first experiment write-up. There are no intentional surprises or tricks to the interview. The questions are:

- Did your people have good communication with each other during the time the experiment was going on? Were they able to follow each other's progress?
- Did the person playing one role know what the reverberations could be of his or her actions on those playing the other roles? Do your perceptions of this agree with what Upper Management observed?
- What did you do to define and interpret the objectives of the experiment for your people before they came into the lab? How did you adjust and interpret these perceptions as the lab progressed?
- What techniques did you use to settle "squabbles" and other "personnel problems" that occurred during the lab?
- Were the objectives of the experiment actually met? What were the results? How did you determine their quality? How do you understand them? Was round-robin testing done?
- How did you reward your people for their efforts and accomplishments? How do you understand your approach here in relation to the results your people obtained?
- What management errors occurred, and how did you make corrections for them as they occurred?
- What kind of debriefing session are you planning to explain to your people the grade you got for your effort, and for them?

These questions form the initial agenda for the management interview. During the interview, time first is spent at a common computer terminal looking at the spreadsheets, any comments written during the lab, whatever brief notes Manager has prepared, and any other related materials such as graphs. Only enough paperwork is sought to document the effort without editorializing in writing so that recall and discussion are clear and easy. Occasionally, a spreadsheet is adjusted and new graphs made on the spot. Then, while the results are on screen, the above management questions are addressed. This opens the door for discussion about the problems Manager had or did not have. With a little receptiveness, the latter parts of the interview usually become quite free ranging.

All Managers start their interview with a grade of "A," which can be progressively lowered if necessary. At the end of the interview, I make a list of problems I have identified. They range from "fatal flaws," which lower the grade, to "minor irritations." Flaws that have been sufficiently serious to lower a grade by a full point (e.g., A to B or worse) include:

- Failure to time/date stamp lab data and related critical records that later would be needed to establish intellectual property rights or liability
- Loss or corruption of electronic data
- Compensation by Manager for an employee's poor work, which resulted in Manager later redoing it.
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• poor understanding on the part of one or another of Manager's people of what was happening in the lab as the work progressed
  • indications that one or another of Manager's people was playing the "zero-sum game" (i.e., improving their perceived lot by comparison to a colleague doing less well, by happenstance or deliberate action)
  • statistically bad results, based on the course database and the results from previous semesters, as well as the results of other companies on the equivalent (or same) experiment (95% confidence limits are used, and poor work is interpreted in the context of the stated objectives of the experiment using a t-test against past means from larger populations)
  • poor graphical presentation of the data, especially as to dividing and labeling the axes so that the trends are readily evident
  • results not available at the time of the management interview ("late work")
  • blunders

An important part of the management interview and final grading is to make sure that Manager understands these kinds of problems. He is his or her liability, regardless of who actually initiated or compounded them. My students hear from me many times, the poignant phrase I first heard from Fred Brech, former director of research of the Jarrell-Ash Division of Fisher Scientific: "When there is trouble in the class, I always look to the front of the room."

The management interview has proven to be an especially valuable part of the whole lab experience, particularly for narrative and anecdotal teaching. There is no question that it is taken seriously. One semester Upper Management "fired" a Manager for an especially crude blunder (an entire experiment was attempted without turning the instrument on) and was forced to continue the interview for another hour to calm the student and discuss how the mistake could have been handled in a professional situation.

Although it is clear that any evaluation procedure may create tension, this mode of lab grading has produced the best educational results of any I have used in my 27 years of teaching. It is not, in itself, more time intensive than grading large, written lab reports. It does, however, prove more emotionally demanding because "active listening" is one of the most effective teaching tools I have discovered for the sessions. A set of written "Tools for Upper Management" has been prepared to assist in the management interview.

The Hawthorne effect

In concluding Part I of this series, it is appropriate to consider the possibility that the success of the role-playing lab is due less to the paradigm and more to my interest in developing the paradigm, the latter being communicated to the students as a subliminal motivator. Informally, this has been called the "Hawthorne effect."

The "Hawthorne effect" refers to increased performance that results from increased attention on the performers. Its historical basis is a series of studies undertaken from 1924 to 1935 by Roethlisberger and Dickson (36) at the Hawthorne plant of the Western Electric Company in Chicago. This was some of the first systematic work in industrial-organizational psychology.

They reported that in one series of quasi-experiments with illumination, workers increased their productivity regardless of the direction of illumination change. Later interpretations (37) have suggested that the effect was due less to lighting level than to the attention paid to the workers while light level effects were being interpreted.

Bloombaum (38) has challenged whether the original "Hawthorne effect" was actually a demonstration of that effect and whether the effect actually occurs in field work or lab work. Cook (39) says that the effect has yet to be convincingly demonstrated in lab or field studies.

However, a similar placebo effect has been well documented (40) in which an unavailing treatment still produces an effect; the mechanism is the person's belief in efficacy of the medicine. Another similar effect is "hypothesis guessing," which has been studied by Rosenthal (41). When hypothesis guessing operates, subjects guess the hypothesis of the study from nonverbal cues the experimenter gives unintentionally and proceed to "help" by behaving in a way that confirms the guessed hypothesis.

If such interpretations are accepted as universally valid and can be extended to teaching developments, it would be possible to suggest that the increased involvement and satisfaction I have observed here in the role-playing experiment had less to do with role-playing than with my attentive involvement with the class. This could be difficult to isolate and verify from the work I have done.
It may be necessary to determine the presence or absence of an operative placebo or Hawthorne effect as part of a professional evaluation of the role-playing approach if it is adopted more broadly (42). In its present context, the issue is immaterial, except in the sense of my being aware that all of the students I have experienced from the role-playing model may not come from the innovation alone. Thus I am on the lookout for ways in which the effect might wane after the novelty has worn off (for the instructor or students), and I will develop further modifications to the method accordingly.

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