

INNOVATIONS IN TEACHING PLANT PATHOLOGY

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■ **Abstract** The teaching environment for plant pathology is changing in both positive and negative ways. Teaching expectations are increasing and resources are decreasing, but recent educational research and instructional technology offer new approaches to meet these challenges. Plant pathologists are teaching courses that may attract new students to the discipline or at least improve agricultural awareness. The Internet offers rapid access to information and images for both students and instructors. Instructional technology provides new tools for classroom presentations, communication with students, reaching new audiences, and distance learning, but using these new tools to enhance learning requires skilled and creative instructors. In the past, many plant pathology instructors worked in relative isolation, but new communication technologies and publishing opportunities for teaching scholarship should improve the sharing of instructional resources and methods.

INTRODUCTION

The last review on the teaching of plant pathology in the *Annual Review of Phytopathology* was published in 1978 and was entitled “Innovative Teaching of Plant Pathology.” The author, Dr. Merrill, discussed many of the themes that still arise in nearly any meeting of plant pathology instructors: the need to better understand advances in learning theory, how to incorporate new instructional technologies to improve learning, and the academic rewards for teaching relative to research and extension responsibilities. Because computer technology is evolving at an incredible pace, the instructional technologies discussed in 1978 seem primitive by today’s standards, but the problems associated with them—cost, time for development, technical support, and the recognition that technology is not a substitute for teaching—remain the same. After 25 years, it is certainly appropriate to revisit this subject and examine some recent innovations and trends.

Plant pathologists teach in many forms and venues, from graduate student advising to extension/outreach programs to traditional classrooms. This chapter focuses on innovation in traditional plant pathology courses taught by plant pathologists at the undergraduate and graduate levels. It is impossible, nor is it desirable, to

catalogue every innovation in teaching plant pathology. In fact, many creative plant pathology instructors have not published their innovations, either for lack of time and/or opportunity, a deficiency that is addressed later in this article. Although certain publications and web sites are noted here for discussion purposes, many quality courses and innovations exist that are not included. Readers are invited to visit several of the cited web sites for access to additional resources. This chapter describes some of the advances and challenges that lie ahead, interpreted through my own perspective, in the hope that all plant pathologists will find the education of our future colleagues and the general population to be worthy of some thought and discussion.

THE CURRENT TEACHING ENVIRONMENT

Most authors who accept the challenge of writing about an impossibly broad subject usually describe the situation as a time of great change or transition. Of course, life is never static, but it does seem that many factors that influence the teaching of plant pathology are changing unusually rapidly. There are both positive and negative influences. It is impossible to predict how some aspects of the teaching environment will evolve, but general directions are becoming evident. There are no simple solutions for some of the most pressing constraints and limitations, but we can feel near euphoria about the progress in other areas. This review focuses quite specifically on teaching plant pathology and cites only a few more general citations in teaching and learning theory. It is hoped that readers will find this chapter useful for discussions about the specific problems they face and that it may also make them more aware of new instructional resources and teaching scholarship related to plant pathology.

This review was written when many major state universities are facing extreme budget constraints. To describe the current environment for plant pathology instruction in the United States, a survey was distributed to individuals at all of the major U.S. plant pathology academic programs. There were responses from 49 programs. Although not a scientific survey, responses to the combination of objective and subjective questions showed several trends.

Existing Programs

Plant pathology remains primarily a graduate major, with only three institutions offering a B.S. degree, although eight other programs offer undergraduate majors with titles that include the words “plant protection,” “crop protection,” or “plant health management.” In the past ten years, eight independent plant pathology programs have been merged to create multidisciplinary departments or the faculty were dispersed to several departments. The new department titles varied; in seven cases, the new title included the words plant pathology, but the discipline name was eliminated in three cases. Three additional departments that were already multidisciplinary were merged into new units with titles that no longer include the words plant pathology. At a single institution (Michigan State University), a

new, independent plant pathology department was formed from a department that had previously included botany. This means that we now have only 19 independent plant pathology departments in the United States, although 8 additional departments are multidisciplinary, with plant pathology in the department title. One must wonder about the repercussions on discipline recognition at institutions where there is no listing of plant pathology as a department or in course catalogues.

Course Offerings

There have been changes in course offerings. Thirteen programs offer more courses, 11 have about the same number of courses, but nearly half of the programs offer fewer courses than ten years ago. The reasons for not teaching courses varied, but often included a lack of faculty with appropriate expertise and/or low enrollments. A number of respondents cited unease about the future of specialty courses that address specific pathogen groups.

Students in Introductory Courses

In the past ten years, the number of students taking the introductory or general plant pathology course is down at about one third of the departments, but higher at the remaining institutions. Plant pathology is no longer a required course in related programs such as horticulture in nearly half of the institutions. The students in the introductory courses have changed considerably, with more students interested in turfgrass and ornamentals than traditional fruit, vegetable, and field crops. Many respondents remarked that students have fewer preparatory courses, a deficiency that affects their ability to learn plant pathology. Specifically mentioned were less knowledge of microbiology and botany and fewer laboratory skills. In most programs the introductory course is taught once a year and mostly by the same instructor(s). There is a single introductory course for both graduate and undergraduate students in all but a few programs.

Distance Learning

Faculty members reported conflicting responses to the questions of whether their institution encouraged them to participate in distance education (most did) and if they did participate (most did not). They cited the potential benefits of reaching new audiences with commodity-specific instruction in a time-independent manner. Commonly listed difficulties in implementing distance learning included time constraints, poor technical support, and lack of new resources. Problems with assessment of the quality of learning, the loss of personal interaction, and difficulties regarding a lab component were also noted.

Instructional Technology

Many faculty members are now using some modes of instructional technology including PowerPoint presentations, web pages, simulations or other

decision-making software, and APSnet Education Center (1) materials. Only a few programs offer online plant pathology courses at this time. Major constraints to using instructional technology include technical support, classroom equipment, and time.

Teaching Expectations

Three quarters of the programs surveyed reported that teaching expectations for their departments had increased. In the absence of increased resources, fulfilling these expectations detracts from research and extension programs. Plant pathology faculty are participating in teaching biology and microbiology courses for majors, biology courses for general education requirements, and “science and society”-type courses.

The Future of Plant Pathology as a Discipline

The survey concluded by noting that although graduate students in plant pathology work on dissertation subjects that span the breadth of biology, we cannot be experts in all areas. It asked if there are core competencies that one should expect for a PhD candidate in plant pathology. Nearly everyone agreed that there were, but defining them was much more difficult. Many respondents noted that their programs were currently trying to determine the answer to this very question. There was near unanimity that plant pathology should continue as a discipline, but widespread concern about the future of the discipline.

Within this climate of tight fiscal resources, a changing student population, and a rapidly changing science that is becoming ever broader while individual scientists are becoming increasingly specialized, instructors are trying to provide an education for students. Some significant innovations have developed since 1978 even though the problems to be solved have not really changed. Instructors are still seeking ways to improve learning and provide information in more interesting and useful ways. In this review, several important areas of innovation are discussed: changing teaching roles for plant pathologists, including teaching methods and teaching to new audiences; instructional technology for traditional classrooms, distance learning, and outreach to new audiences; and instructor communication and scholarship.

CHANGING TEACHING ROLES FOR PLANT PATHOLOGISTS

Teaching Methods

Pedagogy itself is the subject of extensive research. Some plant pathology instructors are turning to advances in scholarship on how people learn to modify how and what they teach (5, 7, 33, 59). Colleges and universities also are expanding the definition of skills required of students in individual courses. Skills in critical

thinking and oral and written communication go beyond simply learning about a discipline (45).

ACTIVE LEARNING Instructors are looking for more forms of active learning to engage students' interest and to encourage class participation (2, 6, 22) through discussions and the application of classroom materials to real problems and situations. A lab on fungal infection processes is enhanced with discussion about the stages of infection relative to application timing and efficacy of a particular fungicide (56). An extension diagnostic problem that resulted in expert legal testimony by a plant pathologist can be turned constructively into a case study (34). Active learning and applications to real-world problems not only give students satisfaction in their ability to use what they have learned but may also increase the likelihood of their retaining the information.

GROUP LEARNING Inquiry-based learning, group learning, and collaborative learning are strategies frequently discussed by instructors seeking to engage students more fully (10, 18, 28). The underlying philosophy is that students will learn more when they are encouraged to resolve problems for themselves and explain their findings to each other. Such activities must be carefully planned, however. Inquiry-based learning fosters in students the excitement of discovery, but they also need enough background knowledge to make progress towards a solution feasible. Theoretically, students should be able to educate themselves with available university resources, with the instructor effectively guiding their learning. For some students, group learning has some advantages by teaching them to work collaboratively through lab exercises or other projects by discussing what is to be done and why. However, some of the more able students may feel restricted when forced into a group whose members do not share an equal commitment to study.

A clear message of recent research on learning theory is that people learn in different ways, a fact that instructors should try to accommodate. In my own labs, certain experiments are done in groups, although individual students are responsible for their own lab reports. Students are encouraged to work in a group, but are given the option to work alone—there are always some who choose that option. In the first session, care is taken to help students who appear hesitant to join a group. Once established, the groups tend to maintain themselves voluntarily throughout the semester, and the students interact more in other lab activities because of the group work. Group learning and inquiry-based learning function well only when students are not in competition with each other for grades. This requires that students be graded on a straight scale rather than a curve, a practice that also encourages them to participate in study groups.

GAMES Some instructors have adapted television game shows to review sessions in plant pathology, and students actually look forward to them. Dr. Stack at North Dakota State University introduced plant pathologists to “Jeopardy” for the classroom in an article in *Phytopathology News* in May 1993. His description is reprinted

in the Instructor section of the *APSnet* Education Center along with sample questions from plant pathologists. Drs. White and D'Arcy introduced "College Bowl" to APS annual meetings as the "DeBary Bowl" in 1993, and the game is now an annual event. Some instructors have used the DeBary Bowl format for review sessions in their own classes (58). Without taking a lot of class time, students enjoy the competition for small prizes, and instructors find it easy to develop review materials for most aspects of plant pathology.

EDUCATIONAL RESEARCH Because the science of learning is an academic discipline and because educational research is outside the purview of most plant pathologists, evaluation of the success of different teaching methods is often difficult. Instructors choose new methods from research on science teaching in higher education and from communications with colleagues with demonstrated success in the implementation of new methods. Most instructors introduce new methods slowly, so courses evolve over time rather than through radical change in a single semester or term. However, once some instructors feel that a new approach is beneficial, they want to make it available to the entire class as soon as possible. Most instructors have neither the inclination nor the resources to conduct formal educational research with their limited student numbers, as their responsibilities in research and/or extension already constrain the time they can commit to teaching. Ideally, when more formal educational research is needed, plant pathologists should be able to avail themselves of services provided by learning specialists within the institution.

GRADUATE EDUCATION There is currently considerable debate about how best to prepare graduate students for their future roles in academic positions (39). In addition to research training, more attention is now given to pedagogical preparation (15). In the past, an apprentice-type system of working as a teaching assistant with a faculty instructor was the informal practice. More institutions are looking toward a more formal approach. A short course is offered at the University of Illinois to help new faculty and graduate students develop teaching skills (42).

Course Content

Most instructors adapt their courses continually to the changing needs of their students. The vast majority of students in introductory plant pathology courses will take one, and only one, course in plant pathology, and that course is likely to be commodity oriented. Therefore, it is important to equip students with the concepts and vocabulary necessary to access our science in any future independent inquiry. Because so many students in our introductory courses are now interested in turf and ornamentals, many of the "classic" diseases are of little interest despite their historical and economic significance.

These same courses also contain students who will be the next generation of plant pathologists. Many of them are not aware that this field will attract them

until they take a course in plant pathology. This is where the role of the individual instructor becomes critical in inspiring them to continue their studies. For these students, instructors must provide the traditional principles and concepts of plant pathology at the same time as introducing them to the incredible advances in molecular biology.

In every program there are debates ranging from the content of the introductory course to what graduate students should know if they are granted an advanced degree in plant pathology. The discipline of plant pathology demands of undergraduates completing a general course and graduate students in plant pathology alike an understanding of the fundamental concepts of diagnosis, the basic biology of the major pathogen groups, host-parasite interactions, epidemiology, and principles of disease management. The importance of each area must be recognized, as well as having an appreciation for what we know and what we do not know for each area. Shouldn't all students who complete the introductory course be exposed to all aspects of the discipline so that they are well prepared to continue their studies once their interest is sparked?

Future plant pathologists will be better equipped to prioritize our limited resources if graduate education requires a set of core courses and attendance at a wide variety of seminars such that they can appreciate the value of all aspects of plant pathology. Reduced communication between those who work in real-time diagnosis and management of current and emerging diseases and those who work in basic research that will guide our progress for the next century will weaken our discipline. Is there a distinction between a PhD in plant pathology or in biology? Shouldn't every recipient of a PhD degree in plant pathology be capable of teaching an introductory course in the discipline?

New Audiences

Although institutional demands for increased teaching by plant pathologists have affected research and extension programs, they have also provided new opportunities for the science of plant pathology and plant biology in general.

BIOLOGY AND MICROBIOLOGY COURSES Participation in biology and microbiology courses for science majors can enrich the education of these students by introducing completely new and fascinating aspects of plant-parasite interactions. Plant pathology offers exciting ways to increase the study of plant biology in biology classes, perhaps even fostering an interest that leads to graduate studies in the discipline.

COURSES FOR NONSCIENCE STUDENTS Although various instructors have offered courses for nonscience students over the years, the new teaching demands have greatly increased the number of institutions offering this type of general interest course related to plant pathology. Some such courses fulfill defined graduation requirements, mostly in the area of biological science, and others fulfill writing or

other nontraditional requirements. Some departments offer courses that students take purely out of general interest. Dr. Hudler's "Magical Mushrooms and Mischievous Molds" course at Cornell University is one very successful example. Not only are hundreds of students introduced each year to plant pathology and its significance, but a much broader audience has also been reached through publication of a book (25) based on the course, which in turn led to media interviews, including National Public Radio. All of us who have had the experience of explaining what plant pathology is to strangers when traveling or in social gatherings can appreciate the value of such positive publicity.

Courses in plant pathology need little justification for their contribution to the education of students. With only a small percentage (2–3%) of people participating directly in agriculture today, the need for some understanding of food and fiber production by students is rarely mentioned in higher education. Thus, courses in agricultural awareness can help students understand the role of agriculture in the nation's economy and, at the same time, learn about the interesting interactions of organisms that we study in plant pathology (43, 46). The practical relevance, historical importance, and ties to culture provided in the study of biology using plant pathology are ideal topics for inclusion in general education requirements for students.

National standards for science education have been published (36), but it remains with instructors to create courses that help the student to meet these standards. A textbook and lab manual to accompany a general education biology course at the University of Wisconsin not only describe how the course is taught, but also emphasize how such courses should help students think about problems (23, 30).

Many scientists question why separate courses need to be offered for students in nonscience majors. The goals and approaches of such courses are very different (3, 46). Science majors are beginning a lifetime of detailed learning about their subject, whereas nonscience students need more general concepts. Nonscience students often lack confidence in their ability to do well in a science course, and many have minimal interest, limitations that must be overcome before any learning can occur. There is often a negative view of scientists as people with limited cultural interests and without a moral vision to their work. Stories of plant pathology and plant pathologists and their ties to culture and history help break down these stereotypes. Interest developed in these courses can sometimes encourage students to become science majors and, possibly, consider plant pathology as a career. At the very least, students will learn enough about science and its ethical dimensions to become better-educated citizens in an increasingly technical world. Many controversial scientific issues require input from both scientists and nonscientists who bring a variety of viewpoints to these complex problems.

Most significant is introducing students to the issues of agriculture. Urban and suburban students require some biological background in order to participate as educated citizens in decisions related to their own health, the appropriate use of genetic resources, land use, rational judgment of genetic engineering, and the risks and benefits of agricultural chemicals.

A website that serves such a course at the University of Illinois, "Plants, Pathogens and People" (<http://www.apsnet.org/education/InstructorCommunication/TeachingArticles/PPP/Top.html>), is accessible by people who are not students in the class. Drs. D'Arcy and Eastburn (19, 20) also have produced two videos, one on Dutch elm disease and one on late blight, for use in their general education course. These videos, available through APS Press, emphasize the historical and cultural aspects of the epidemics and use them to illustrate the germ theory and the risks and benefits of monoculture in ways that are appealing to urban and suburban students.

Most college graduates are not science majors, but they will be voters, legislators, judges, and taxpayers. As stated in (46), "Never in history has the knowledge of science been more important in society. Never in history have most people been so removed from the production of their food." We are still struggling with the appropriate response to recent terrorist attacks and the potential risks to human and plant health in our country. A better-educated electorate will be able more appropriately to assess risk involved in "homeland security" if they have enough background in biology to make reasonable judgments. When people feel ignorant about a subject, they tend to take conservative stances out of fear of the unknown and the inability to judge risk.

OUTREACH TO K-12 TEACHERS AND STUDENTS When many students and colleagues at our universities are unaware of plant pathology as a discipline and the number of plant pathology departments is diminishing, outreach to K-12 teachers and students can contribute to agricultural awareness and encourage study of plant biology. Dr. Carroll (12) published *Learning Biology with Plant Pathology* through the National Science Teachers Association in 1994 to encourage teachers to introduce plant pathology into their curricula. Additional outreach materials are now available in the K-12 section of the APSnet Education Center (1). The Youth Programs Committee of the American Phytopathological Society (APS) sponsors teacher workshops and arranges for plant pathologists to attend professional meetings of teachers. Many individual plant pathologists visit classrooms in their local schools, assist students with science fair projects, or serve as judges at science fairs, whereas others contribute to the professional development of teachers through courses and workshops (37).

LIFELONG LEARNING One can no longer claim that the education obtained in a typical undergraduate or even graduate program is sufficient in our rapidly changing world. As career changes over a longer working life become routine, education, both formal and informal, becomes a lifelong preoccupation.

Plant pathologists have traditionally provided educational services through extension education programs for growers, county agents, master gardeners, and others. With diminishing resources and the demand for easier access to information, the Internet is becoming a resource for these same audiences. The International Certified Crop Advisors (CCAs) Board (26) offers self-study units for

up to 20 of their 40 continuing education units (CEUs) required in the two-year cycle (http://www.agronomy.org/cca/self_study.html). Dr. Vincelli (57) recently published an online overview of the QoI/strobilurin fungicides for plant pathology students in the advanced section of the APSnet Education Center, and the unit was approved for CEUs for CCAs as well (<http://www.apsnet.org/education/AdvancedPlantPath/Topics/Strobilurin/top.htm>).

INSTRUCTIONAL TECHNOLOGY

Images

In the past, probably every plant pathology instructor has felt limited by the supply of images of diseases and pathogens, especially for the introductory courses. Now extensive collections of digitized images are available for instructional purposes. This rich supply of images can be used in classroom presentations or online study guides to enhance learning in significant ways. As stated above, students learn in various ways, so the more ways that we can offer them to learn, the more likely it is that an individual student's needs will be met. Study guides of computerized materials help prepare students for what they will see and do in laboratories. An image resource also is helpful for review of materials from past classes and for use when a class is missed. An image collection furnishes information about diseases according to their commodity interests and about disease problems from distant regions and foreign climates. Most students study plant pathology during the winter months when living materials are in short supply in many regions. Electron micrographs can enhance the understanding of host-parasite interactions when combined with standard microscopic views. An exciting new set of short videos combines photography of diseases in the field and microscopic images with realistic animations of sexual reproduction, spore dispersal, and the early stages of infection (55).

IMAGE COLLECTIONS Access to image collections is rapidly improving. A collection of nearly 10,000 images with an accompanying database for image identification is available on a videodisc published by APS Press (53). Introductions to the major pathogen groups and some lessons on example diseases are available at no charge in English, French, and Spanish, together with image numbers (48). Advances in videodisc technology allow a large collection of images to be viewed on a single disc, with repeated uses of images for various applications with minimal equipment (videodisc player and television). A student study station can be created with the videodisc and a TV, but multiple users at various sites require digitized images in computerized programs. APS Press now offers CD-ROM collections of commodity-based images and a collection of images from previously published slide sets on the major fungal pathogen groups.

IMAGE USES Images can now easily accompany glossaries or hypertext links to new vocabulary in published materials (17). Many important terms in plant

pathology are essentially meaningless to students without images. Keys used by professionals to identify diseases and pathogens can be modified to include diagrams and photographs along with explanations of new vocabulary to enhance students' understanding of relationships. Without these enhancements, many keys are unusable except by experienced pathologists, who are already familiar with the organisms and their features.

Various software packages using digitized images are available for lecturing, of which the most popular program probably is PowerPoint. This program makes preparation of relatively sophisticated presentations fairly simple. However, many classrooms, although equipped with slide projectors, still do not have computer (liquid crystal display/LCD) projectors; instructors are understandably reluctant to carry a computer and LCD projector to each class. Even in equipped classrooms, until recently, the instructor still needed to bring a computer, which might not be compatible with the projector. Computer projectors are now much smaller, less expensive, and easier to transport. In addition, some "data" computer projectors have a PowerPoint slide viewer feature. Used with a USB CompactFlash card reader/writer that hooks up to the computer's USB port, PowerPoint files can be downloaded to a CompactFlash card, which can then be inserted into the projector without the presence of the computer.

CAUTIONS FOR IMAGE USES It is easy to be distracted by the glitz of PowerPoint presentations and their potential features. Information can be presented in a clear, step-by-step format far exceeding what is possible with standard slide or blackboard presentations. However, there are drawbacks.

- 1) Although multiple images on a screen can look appealing, considerable detail is lost with the diminished size of the image.
- 2) Too much text is often included in the presentations. A few bulleted points that include any unfamiliar terms should guide the audience. Listening to a presenter and reading a long textual statement is not possible at the same time.
- 3) Complicated mixes of fonts and colors can be jarring and tiring to the eyes. Slides fail to indicate the relative importance of information if everything is presented in large bold letters or clashing color schemes. Not all color schemes will necessarily project well. Certain color combinations will be difficult to discern for students with various forms of color blindness.
- 4) PowerPoint presentations may appear superior in clarity to slides or a standard blackboard presentation, but one must remember some limitations of the audience. It is very easy to go too fast for those trying to take notes or understand new concepts. A complementary tool is to give students an outlined handout on which they can make personal notations. Alternatively, the entire presentation can be made available through a website or distributed in a paper copy. There is a tendency for attention to flag when people perceive that

they do not have to take an active role. Class attendance may even decline. If students are not participants in the learning process, even the most appealing PowerPoint presentation may not really enhance learning. Overuse of even appealing presentation formats can lead to boredom and reduced interest.

There is an additional important caution about the use of images in plant pathology instruction. There is no substitute for the real experience of working with plants and their pathogens with microscopes and other lab tools to learn size perspective and the variations that occur in real life. A commonly observed phenomenon is that students can make identifications from projected images, but have difficulty when examining living materials, and sometimes even prepared slides. Although image resources can enhance learning, they cannot substitute for lab and field experiences.

Computer-based Teaching Tools

Simulations and other programs can help students make decisions using what they are learning about plant pathology. DiagnosisTM is an excellent program to help students use their powers of observation and simulated laboratory results to diagnose disease problems. Some sample scenarios have been prepared as well as a program “shell” with which instructors can prepare their own scenarios. As part of Dr. MacHardy’s course at the University of New Hampshire, students prepare their own diagnosis problems (personal communication). Dr. Stewart of Massey University, who created the Diagnosis program, has described it in more detail (49, 52). Development of additional scenarios that could be shared would contribute greatly to the value of this program for students, but few instructors have time available. Stewart suggested that recently retired plant pathologists might be excellent authors of new diagnostic modules for plant pathology students, based on their years of experience.

COMPUTER GAMES Several computer games, including AppleScab, LateBlight, Resistan, and TurfBlight (44, 50), help students apply what they have learned when attempting to manage the various diseases and avoid fungicide resistance. Dr. Arneson (personal communication) has recently been involved in modifying three of these for web-based formats. Although the currently available version of AppleScab is an old DOS-based program, I still use it in my introductory course. Student reports clearly demonstrate that they were challenged by keeping track of weather, fungicide applications, inoculum levels, and tree phenological development. Even the most “organically” oriented students felt a sense of panic when the scab graph continued to rise uncontrollably. Many students expressed sympathy for growers who have to battle this disease.

DECISION-MAKING TOOLS Any situation has value that allows students to apply what they are learning during a course to solve a problem. Entertaining

computer-based games can be enjoyable, but there are not many available. Even non-game sites can be interesting and useful, such as the peanut/*Tomato spotted wilt virus* website (13). In the best applications, students can try many different approaches to solving a problem in a relatively short period of time and at no financial risk.

COMPUTER-BASED INSTRUCTIONAL MATERIALS Textbooks and computer resources can be combined in creative ways to enhance teaching in many areas of plant pathology. For example, *Exercises in Plant Disease Epidemiology* (21) includes computer discs that contain public domain software, example data sets, and annotated computer code for statistical analysis. Simulated laboratories for nonscience students in a general education course have been developed at the “Plants, Pathogens, and People” web site at the University of Illinois (16).

CD-ROM technology can be used to modify existing resources to make them more accessible for a variety of users. For example, the *Compendium of Turfgrass Diseases* was reformatted into a CD-ROM version (47) to make the information more useful to students and more accessible to working professionals who are not plant pathologists.

The core of information on each specific disease was modified so that images and text were placed together, whereas images were on separate plate pages in the printed version of the *Compendium*. Disease information was organized using the same categories each time so that users could easily find what they needed. The more applied information was separated from the more technical details to reduce confusion by less educated users. Disease cycles were highlighted with pop-up images. Pop-up squares highlight various sections of the disease cycles to guide readers when colored words are clicked on in the accompanying text. Each disease section has links to diseases with similar symptoms. Disease management recommendations were expanded and, in some cases, separated into different lists for lawns and golf courses.

Access to this core of information is possible from a number of entry points: the index, an illustrated key to diseases, the image browser, and the host-specific disease calendars. This helps users find the appropriate disease section depending on information available to them. For all users, the information was “layered” to first provide a general overview followed by increasingly detailed information.

There are many existing plant pathology resources that could be made much more accessible through modification into a CD-ROM format. Extension personnel can bring their expertise to students and other nonspecialists with the use of CD-ROM technology and extension web pages, and many are already doing so.

Access to Information

The Internet allows rapid access to unlimited current information related to plant pathology in presentations that are image-rich, colorful, and animated, all more attractive than standard textbooks. Students can access this information from a

computer at any location, a factor that may be more conducive to research on topics of interest than traditional modes of research.

However, use of this vast new resource also poses new pitfalls for students. Plagiarism is all too easy, and not all students are even aware that this is an inappropriate activity. Students have limited skills to determine whether a site is a reliable source of information. Critical evaluation is an essential skill in the training of students. Unfortunately, students can easily confuse “point and click” with real learning; when so much information is easily accessible, students may believe that they no longer need to commit anything to memory. The vast amount of information now at students’ fingertips can be overwhelming and hence time-wasting as they cannot discriminate between sites that are either unreliable or unrelated to their needs. More positive are sites such as the Plant Pathology Internet Guidebook, created by Dr. Kraska (29), where many of the available sources of information have been organized and evaluated.

The ease with which information can be obtained from the Internet may limit the use of older, valuable library resources. Because many older publications, including books, journals, and extension publications, are not available in digital form, they often are ignored. This failure severely decreases the accuracy of a literature review and can lead to redundant research.

Digital search mechanisms are, of course, of unparalleled significance in providing materials of interest to the searcher. However, missing in this use of technology is the serendipitous discovery of interesting and useful information when leafing through journals or books.

Course Web Pages

Course web pages are now commonly used for routine communications between instructors and students, offering access to materials such as the syllabus, practice quizzes and old exams, and misplaced class handouts. A course web site also can give students links to enrichment materials at other sites preselected by the instructor. Instructors can post PowerPoint presentations from classes or post all of their lecture notes relatively quickly. Other instructors are creating elaborate presentations to supplement their class time, but this generally requires more time and resources than are typically available (3, 38).

The APS*net* Education Center (1) was created to prevent redundancies in online study materials for students. A goal of the free site is to provide a central resource where many standard materials, such as disease lessons and an illustrated glossary, can be posted. Experts with high-quality images can contribute to their area of specialty, and students at many institutions can benefit. Instructors of individual courses can then link to these standard materials from their personal websites.

The technical support provided to authors by the staff at APS allows instructors to focus on content rather than on the technical basis for instructional technology. Improved technical support will allow all instructors to enhance their teaching with these new tools. As noted above, most instructors are already balancing teaching

obligations against research, which is the primary source of monetary reward and career advancement. Many instructors have very creative ideas about how to better present materials to students but need the technical backup that is sadly lacking at many institutions to bring these ideas to fruition.

Distance Learning

Distance learning, which has been available for more than a century through correspondence courses and the more recent television and videotape courses, continues to be offered in various formats. Advances in instructional technology have caused many universities to encourage their faculty to participate in distance learning.

Online courses that can be offered asynchronously to anyone with Internet access are becoming popular (14), with instructor-student and student-student interactions through email and bulletin boards. Students and instructors can even communicate in real-time from multiple locations. Drs. Bender, Dickman, Leach, and Wolpert have used Internet 2-based technology to create an advanced microbial genetics course with students and instructors from Kansas State University, Oklahoma State University, Oregon State University, and the University of Nebraska (31). Such a course requires detailed planning and faculty commitment, but students benefit greatly from multiple instructors with complementary areas of expertise. They also profit from observing the professional interactions of the faculty. Although costly in terms of instructor time and the technology required, this collaborative approach has great potential for providing upper-level courses, especially when there is no appropriate instructor at a particular institution.

Traditional on-campus plant pathology courses with a standard laboratory component allow the instructor to work with students on a weekly basis in a hands-on, informal environment. Laboratory work is an essential complement to formal lectures and is probably most effective when required weekly over a period of time. Offering plant pathology courses with a laboratory component through distance learning is problematic, although creative solutions have been devised. At the University of Georgia, students come to campus for some all-day or half-day sessions to fulfill the laboratory component (32). At North Carolina State University, a plant pathology course is offered with interactive television, and the laboratory component is provided at each of three sites where students attend (24). Both courses are aimed at working adults who are unable to participate in a full-semester, on-campus course.

The many forms of instructional technology are still at such early stages that there are few standards and little evaluation of the quality of learning that is derived from it (35). Educational research aimed at such evaluations is under way, and some plant pathologists have published critiques on the use of instructional technology in their courses (27).

Cautions

Web-based or computer-based learning tools have tremendous potential, but require caution. The same advantage of three-dimensional access to information can

result in students being lost in the “web” of information. Connections may be obvious to those familiar with the subject, but not to the novice. Navigational tools that guide students back to main menus and submenus are necessary to prevent this confusion.

Another danger in creating these tools is oversimplification. If students are only presented with the shortened versions of important concepts required for appealing web-based presentations, they will not develop essential higher-order thinking skills. Long segments of text are uncomfortable to read on a computer screen and are probably best presented in print. Most instructors are quite familiar with the phenomenon of students printing out web-based materials for later study to avoid long periods at the computer screen.

Not all students have high-speed Internet access. This problem, albeit probably short-lived in the United States, impedes access to information that must be downloaded over a phone line. Students in countries where Internet access is slow, unreliable, or unavailable will also find these resources difficult to use. CD-ROMs of instructional materials can provide an inexpensive and efficient alternative means of access. Some links to additional materials on the Internet will be lost, but the bulk of the information will be easy and fast to access.

Many instructional technologies have been developed and abandoned over the years. In the 1940s and 1950s, some materials were made available on records. In the 1960s and 1970s, televised lectures, live or videotaped, were popular for large lecture classes. Many general biology classes were converted into autotutorial labs in which students listened to tape recordings and worked in small booths in isolation from classmates and instructors. In the 1980s, videotapes became popular. The 1990s saw an explosion of computer-based technologies with digitized images and Internet communications. Throughout these decades of technical progress, published research suggests that, as measured by standardized tests, students frequently do as well when educated with technology as in standard classrooms (41). Unfortunately, there is no explanation why many early technologies were abandoned even before improved substitutes were available.

Apparently, instructors and students were not satisfied with the learning environment that was created. This conclusion suggests that student performance on the tests used in these published studies may not be the best measure of the delivery of education. In introductory courses in particular, the role of the instructor goes beyond delivery of information specific to the discipline to creating interest in the subject and making connections with learning in other courses. Instructors have a responsibility to test students not only on rote memorization, but in ways that encourage applying what has been learned to new situations. Learning should be assessed in more ways than through examinations; writing assignments, problem sets, lab worksheets, and class participation all allow student progress and learning to be assessed.

Contrary to the expectations of many university administrators, high-quality online courses are likely to cost more and require more instructional time than traditional classroom teaching (54). The use of instructional technology for courses

by CD-ROM or via the Internet will probably be most useful to adult students who need to update their learning or who are changing careers (51).

The best ways to incorporate newly available online resources into courses are still under debate. Advice is available for instructors who wish to use instructional technology and/or participate in distance learning (4, 8, 9, 11, 35, 40), but instructors themselves must make the final decisions about how best to help their students learn. Most instructors seem to enjoy the newly expanded menu of choices and make their choices according to course content and the student population.

INSTRUCTOR COMMUNICATION AND SCHOLARSHIP

Plant pathology instructors often work in relative isolation. Teaching committees of professional societies offer sessions and discussions at annual meetings, but otherwise there is often little communication among instructors. Depending on the university, faculty members who are interested in teaching meet with each other, but these meetings are not necessarily relevant to plant pathology. The Internet again provides new means of access for instructors who wish to interact throughout the year. Teaching committee web sites are an obvious potential support.

Attendance at professional meetings may be limited by financial exigencies or teaching obligations. Instructors from countries with limited resources find it especially difficult to attend international meetings. The past two International Congresses of Plant Pathology held workshops on information and instructional technology. Participants demonstrated their programs but were limited in their interactions with the other participants. Some programs required working time substantially beyond that of the workshop to be fully comprehensible.

The Teaching Committee of the International Society for Plant Pathology (ISPP) held a free, online Instructional Technology Symposium from 15 May through 30 June 2001, with financial support from the ISPP Executive Committee and web-hosting by Massey University. Authors of the online papers could provide links to additional web sites where more information or use of sample programs was made available. Because the Symposium was online, anyone could participate at no cost whenever individual sessions were open for discussion, and no travel costs were incurred. Dr. Stewart was the webmaster for the event, while members of the ISPP Teaching Committee reviewed the papers, organized the sessions, and served as moderators during the Symposium. Authors from 7 countries submitted 26 papers. Each week a set of papers, a specific forum topic, and a general discussion forum were open for online discussions among the authors and Symposium participants. There were 321 registrants from 48 countries. Many of the participants did not interact in the discussions, perhaps because of language limitations or lack of interest. There were no identifiable technical problems, and the large and diverse body of registrants suggests that this is a format that could be used for future symposia. The Symposium has been archived online and includes

many interesting papers and discussions on instructional technology for plant pathology (27).

THE APSnet EDUCATION CENTER

One of the main goals of the APSnet Education Center (1) is to provide a central site for peer-reviewed instructional publications for plant pathology. Categories include disease lessons, lab exercises (K-12, introductory, and advanced), subject matter presentations (introductory and advanced), an illustrated glossary, and additional resources. Because the site is free, it can serve as an enrichment resource for plant pathology courses. Each instructor can teach his or her unique course and link it to selected materials in the APSnet Education Center, thereby eliminating the redundant creation of standard materials and giving students access to information from authors who are specialists. Definitions in the illustrated glossary can be linked to terms within instructor-created materials. The Resource Catalogs include annotated listings of instructional resources such as videos, books, and websites. Inexpensive CD-ROM versions of the site are updated annually and available for teaching venues and student use where Internet access is slow or unavailable.

A peer-reviewed journal, *The Plant Health Instructor*, is part of the APSnet Education Center. Publications are given a citation similar to those in research journals, i.e., a Digital Object Identifier (DOI) that provides permanent online access to the publication. Creative instructors can share their instructional materials and perhaps receive institutional recognition for their efforts.

Although the APSnet Education Center provides materials designed for standard plant pathology courses, they could also be used in biology and microbiology courses. It is hoped that the ease of access to the labs and other publications will encourage instructors in those courses to include some plant pathology. They also may aid plant pathologists who participate in such courses, where students do not own plant pathology textbooks, because images and background materials are free and online. In a broader outreach, the K-12 section is designed to help teachers bring plant pathology and agricultural awareness into their classrooms by providing labs that can be readily incorporated into their curricula as well as the necessary background materials, lesson plans, and instructions. An exercise is even available for early elementary students. Teachers also are provided with monthly "News and Views" related to plant pathology, online mentors, and a catalog of additional instructional resources.

The Instructor Communication and Scholarship section is designed to encourage interactions among instructors and to provide a central location for the publication of peer-reviewed educational scholarship related to plant pathology. Although some plant pathology instructors publish in several teaching journals, these articles may be missed by their teaching colleagues and administrators who often do not subscribe to or regularly read these journals. Both peer-reviewed teaching notes and teaching articles can be published in *The Plant Health Instructor*. Teaching notes offer the opportunity for instructors to share innovative lab or classroom

successes with their colleagues. Instructors also can share exam questions and read the answers to the discussion questions of online labs and exercises in the password-protected section.

The creation and support of the *APSnet* Education Center reflect a commitment by APS to teaching, outreach to new audiences, and teaching scholarship. The Don and Judy Mathre Education Endowment Fund of the APS Foundation was established in April 2002 and has been designated primarily to benefit the *APSnet* Education Center. This generous base of support can continue to grow with additional contributions.

CONCLUSIONS

This is an exciting time for education in plant pathology. Many of us are teaching to a student population very different from that of our own instructors. We are teaching students with different commodity interests and preparing courses for new audiences where students may not even be science majors. We also have a far wider choice of tools that may enhance learning. Our students now have rapid access to images, animations, simulations, and vast amounts of information. Plant pathology instructors have new ways to communicate with each other, to share instructional materials, and, perhaps, to gain some recognition for their creative scholarly contributions in teaching.

Any discussion of teaching usually ends with successful teachers reflecting on the relationship between students and instructors and how these interactions are governed by traits of both the student and the instructor. There is no one right way to teach, just as there is no one right way to learn. Highly motivated students will learn under nearly any circumstances. The challenge lies in the delivery of quality education to good students who do not yet appreciate the new discipline. Students who may not be academically oriented but require an understanding of plant diseases in order to make their living from plants are also looking for a useful education. An alert teacher continually assesses the level of learning in a classroom by eliciting questions from students or by observing a look of confusion. No computer program can replace these qualities in an instructor.

Luckily, despite the resounding negative institutional messages, there will always be teachers who will stop to answer a question, offer advice, or simply make a student feel that someone has a personal interest in him or her. These teachers will be successful with or without computers, digitized images, and multimedia extravaganzas. They are the people who understand the human value of teaching and learning. Anthropologists have speculated that human evolution was strongly influenced by speech because this means of communication could be used to quickly spread new information and ideas. There is a very strong urge to share new ideas and insights that we find exciting with those around us. Instructors with that same urge to share the excitement will inspire the next generation of plant pathologists and, of equal importance, people who appreciate plant pathologists.

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The *Annual Review of Phytopathology* is online at <http://phyto.annualreviews.org>

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