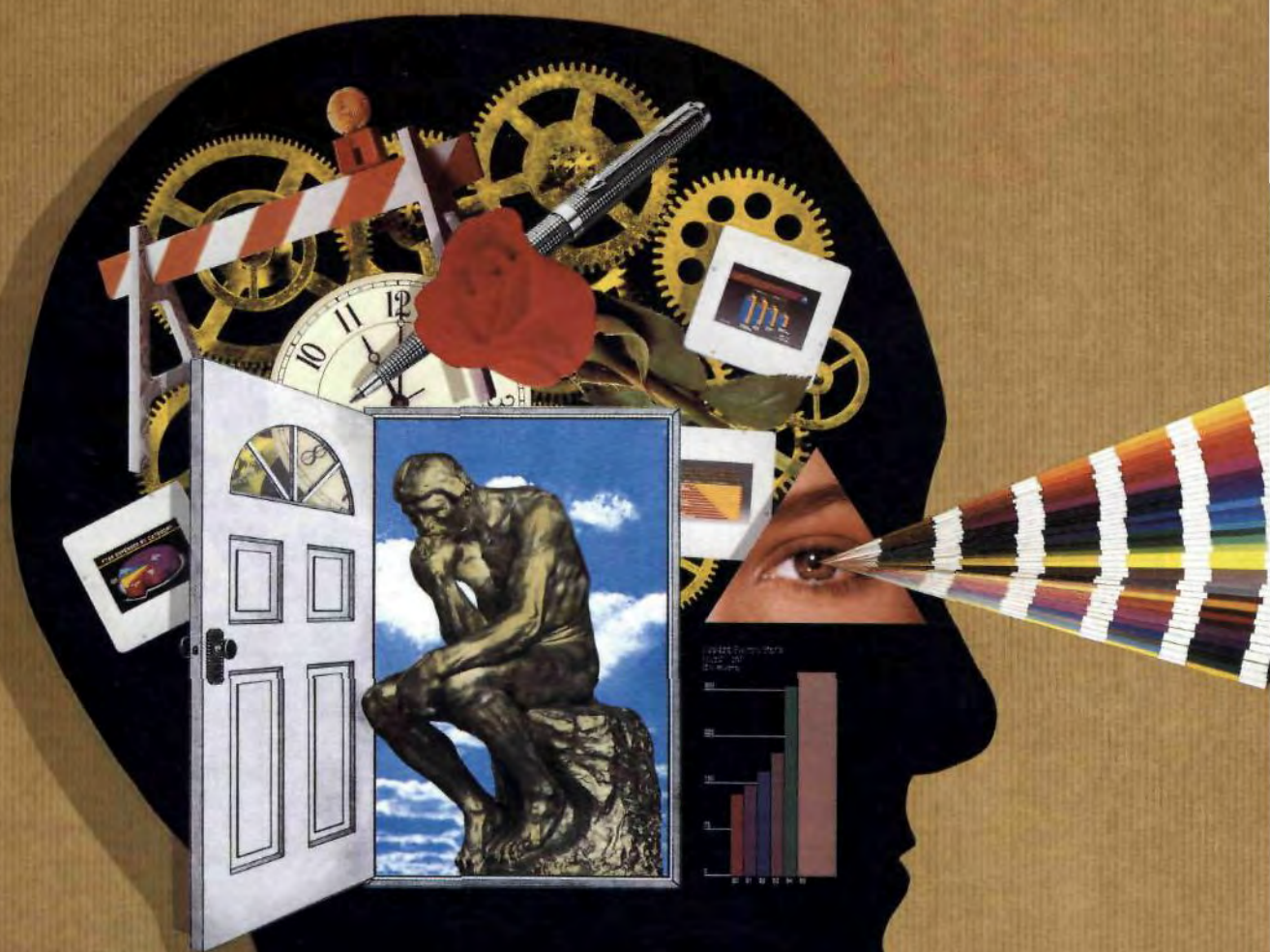


TEACHING
CLINICAL
REASONING

Summer 1990
Volume 15, Number 4

JOURNAL OF OPTOMETRIC EDUCATION



Acquisition • Retention • Application

Association of Schools and Colleges of Optometry

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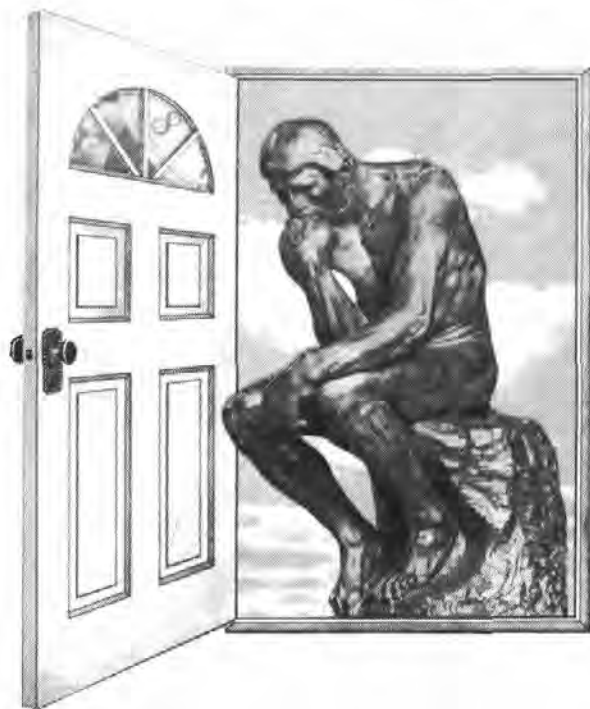
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Teaching Clinical Reasoning

"Scientific reasoning . . . is a constant interplay or interaction between hypotheses and the logical expectations they give rise to; there is a relentless to-and-fro motion of thought, the formulation and rectification of hypotheses, until we arrive at a hypothesis, which to the best of our prevailing knowledge, will satisfactorily meet the case." Peter Medewar, *Pluto's Republic*, 1984.

Depicting the reasoning process as a to-and-fro motion of thought may be as good as any to describe the way we are thinking when we elicit a case history from our patients and proceed with the examination. Our ability to teach clinical reasoning is expanding through a greater understanding of our own cognitive processing, elicited by introspection, along with a greater familiarity with educational and psychological research in the area of clinical reasoning.

The critical role faculty play in developing clinical reasoning skills in our students has been alluded to in a couple of recent JOE editorials — "The Curriculum Crunch" and "Professionalism and the Life-Long Learner." This issue of the *Journal of Optometric Education* is devoted to an exploration of the clinical reasoning process and provides practical suggestions for integrating this dimension of education into didactic and clinical curricula through problem based learning theory.



The decision to devote an entire issue of JOE to teaching clinical reasoning was based on a belief that this area represents one of the greatest challenges of the next decade for optometric education. The challenge stems not from the addition of some new complex area of knowledge, but from the need for us as faculty to reassess and fundamentally modify our own behavior as teachers. Modifying our teaching methods to increase the emphasis on the cognitive process involved in clinical reasoning is not an easy task. In fact, our own backgrounds as students serve to reinforce a style that embraces the traditional lecture and often stimulates a knee-jerk reaction against the need for alternatives: the "it worked for me, so it must be okay" response. Breaking from that format requires a conscious effort before and during the act of teaching, as well as a willingness to commit time to develop an understanding of the discipline of cognitive science.

This issue of the *Journal of Optometric Education* is a compilation of articles developed by the participants in a symposium, "Teaching Critical Thinking," presented at the 1989 meeting of the American Academy of Optometry. These articles represent a significant first step for optometry in the effort to respond to the challenge of teaching clinical reasoning. Included is a comprehensive discussion of cognitive issues, an overview of the fundamentals of problem based learning as a methodological paradigm and practical suggestions for the integration of problem based learning techniques into both didactic and clinical teaching.

From my discussions with faculty across the country, it is evident that there is a growing community within the schools and colleges of optometry for whom teaching clinical reasoning and developing new and more effective teaching methods represents an exciting challenge. It is critical that efforts to meet the challenge be shared. I would specifically encourage readers to submit short teaching methods articles, commentaries and letters to the editor, allowing the *Journal of Optometric Education* to facilitate the exchange of innovative methods that encourage the development of clinical reasoning in our students.

David A. Heath, O.D.
JOE Editor

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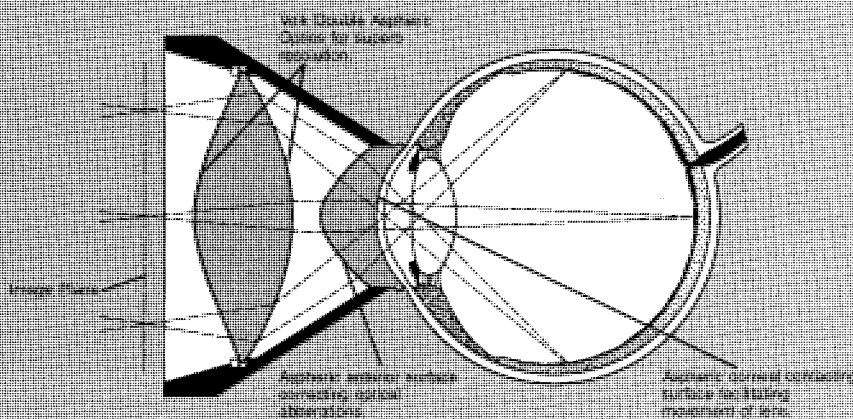
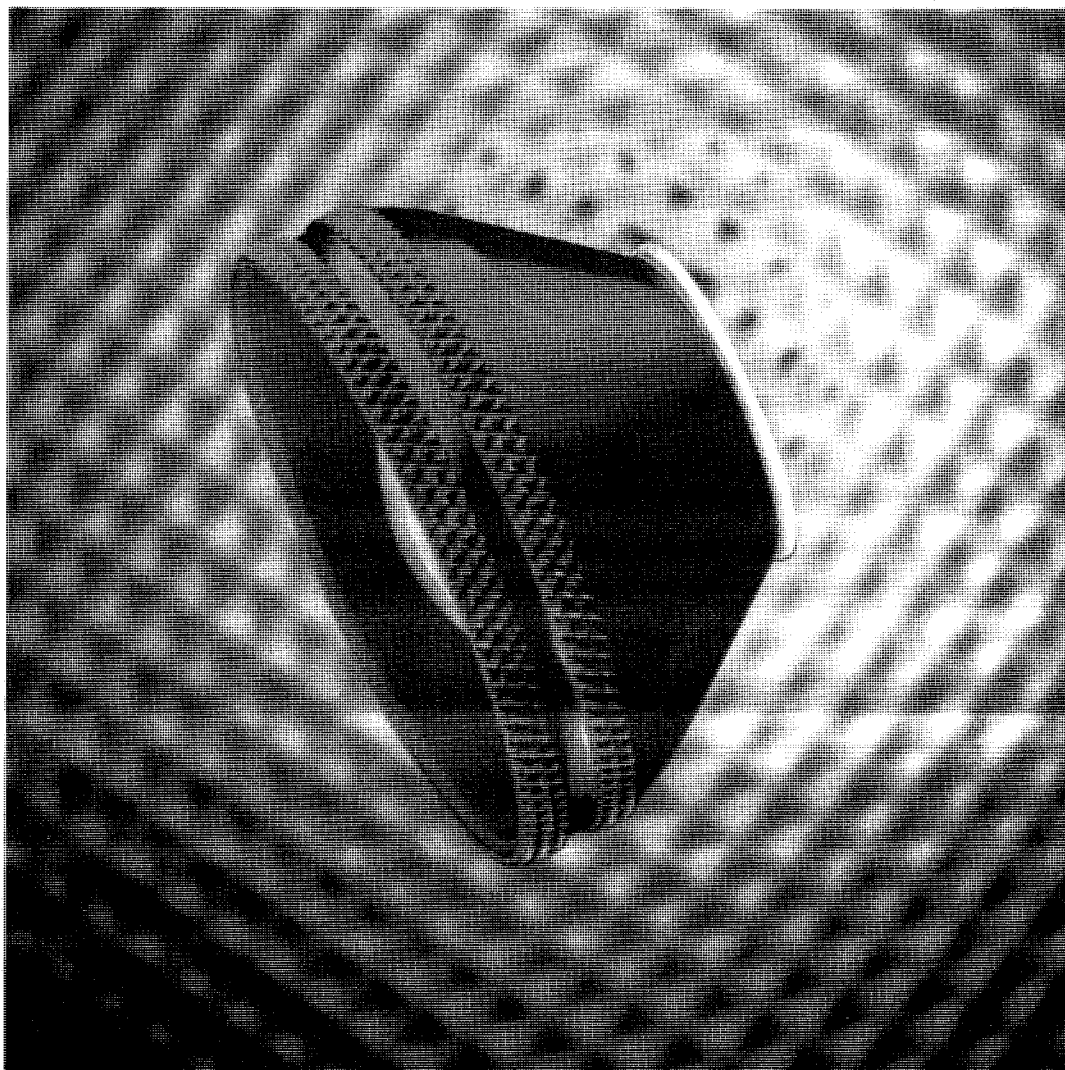
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BOSTON® RXD™ Performance Kit Available

Polymer Technology Corporation now offers the BOSTON RXD Performance Kit which contains all the information needed to successfully fit the new BOSTON RXD daily wear lens.

The kit contains a complete fitting guide, product information, patient brochures, and an attractive waiting-room display card which is an ideal tool for calling consumers' attention to the BOSTON RXD Patient Brochure. Also enclosed is the special practitioner's edition of the *BOSTON Lens Newsletter* which features a practice management discussion by leading fitters.

"The BOSTON RXD Performance Kit was designed to help practitioners successfully fit this new, fluorinated, daily wear contact lens," said Colleen Janick, Marketing Manager, U.S. Materials. "We added the special practitioner's edition of the BOSTON Lens Newsletter as an educational tool for practitioners to better understand issues that closely relate to their own practices," she added.

To receive the free BOSTON RXD Performance Kit, practitioners may call Polymer Technology at (800) 333-4730.

Ross Laboratories Plans Meeting With Ohio State

September 7, 8 and 9 are the dates announced for the 1990 Ross/Ohio State National Contact Lens Meeting. The multidisciplinary meeting, which last year attracted nearly 700 ophthalmologists, optometrists and opticians, will be held at the Hyatt Regency/Ohio Center, Columbus, Ohio.

"Last year's inaugural meeting was so well received that the 1990 meeting will have the same format—four, three-hour sessions featuring 20-minute presentations from experts in the contact lens arena. We'll also offer 12 free hours of continuing education credit to all participants," said Murray Sibley, Ph.D., director of research and development, Lens Care and Consumer Products for Ross Laboratories.

Joseph Barr, O.D., M.S., assistant professor, The Ohio State University College of Optometry and Richard Lembach, M.D., associate professor, The Ohio State University College of Medicine and president of CLAO, will co-chair the meeting.

The theme of this year's meeting—Contact Lenses for the 1990's—was chosen because the next decade promises to be an exciting and innovative time for the contact lens industry," said Dr. Lembach. "The four topics to be discussed at this year's meeting include 'Rigid Gas Permeable Lenses,' 'Contact Lens Issues and Answers,' 'Presbyopia and Contact Lenses,' and 'Contact Lenses in the 90's—Future Trends,'" added Dr. Lembach.

Registration forms will in upcoming issues of *Contact Lens Spectrum*, *Contact Lens Forum*, *CLAO*, *20/20*, *Ophthalmology Times* and *Opticians Association of America News*, or call your Murine Lens Care representative. For more information on the meeting, call (614) 229-7178.

W-J Backs Complements with New Training Program

To support its \$8.5 million consumer advertising campaign for Complements, the new generation of natural-looking opaque lenses, Wesley-Jessen Corp. has developed a new training program for dispensers and contact lens technicians.

Called "Sharing Complements—An Assistant's Guide to Complements by DuraSoft Colors," the training manual is designed to help assistants translate patient interest in the new line of lenses into successful colored lens wearers.

"An office staff that passively waits for patients to request DuraSoft Colors or Complements may fit a pair a week. Another practice with a similar patient base can easily fit three or more pairs a week. All that's needed is mastering a few simple techniques to make patients aware of colored lenses and to present them effectively," said Brian Regan, W-J's Product Manager. "The difference between one and three pairs fitted per week can be more than \$30,000 in revenues per year," he added.

Pilkington Supports Poland's Optometry School

Pilkington Visioncare has helped advance the establishment of an optometry college and eye clinic in Poland with an unrestricted cash grant of \$20,000 to American Friends of the Marcinkowski Academy of Medicine (AFMAM). The grant was presented to AFMAM Chairman Michael J. Obremsky, OD, by Donald J. Ratkowski, President of Pilkington Visioncare's Paragon Optical subsidiary.

"Optometry as it is known and practiced in the United States does not exist in Poland. The first step in developing primary eye care there is to establish a college of optometry and an optometry clinic that will serve as training grounds for native practitioners," according to Ratkowski. He continued: "We hope that some day Poland will serve as an eye care model for other Eastern European nations." The curriculum for the optometry college will be modeled after American schools and feature faculty and student exchange programs. AFMAM's goal of raising \$250,000 in cash and equipment is, with Pilkington Visioncare's contribution, now about one-third realized, according to Ratkowski. Individuals or companies wishing to contribute may do so by sending their donations to: American Friends of the Marcinkowski Academy of Medicine, c/o Foundation for Education & Research in Vision, Inc., P.O. Box 14170, Houston, TX 77221.

Pilkington Visioncare is an international provider of ophthalmic goods, equipment, and other vision care products. Pilkington Visioncare is comprised of Sola/Barnes-Hind, Sola Optical, Coburn Optical, Paragon Optical, and Pilkington Visioncare, International.

New Varilux Vision Today Patient Newsletter

Varilux Corporation announces the availability of *Vision Today*, an all new patient newsletter.

The 4-page newsletter is available to practitioners in quantities up to 1,200 at no charge based on their agreement to redeem an enclosed \$20 off patient certificate. Additional quantities and 100% postage reimbursement also are available through the Varilux 1990 Maximizer Co-op Program.

"*Vision Today* has something for everyone," according to Kevin Jenkins, Varilux Marketing Manager. "For patients, it provides a terrific source of eyecare and eyewear information in an entertaining format. For the practitioner, *Vision Today* is a highly targeted tool for building a practice."

For more information about *Vision Today* and the Varilux co-op program, simply contact the Varilux Marketing Department at 1-800-BEST-PAL.

Vistakon Lens Now Most Prescribed For New Soft Lens Patients

Vistakon, Inc., a Johnson & Johnson company, announced that 1989 fourth quarter results* indicate that its ACUVUE® Disposable Contact Lens has become the most prescribed soft contact lens for new patients, a category that includes both initial fittings and patients refit from other lenses.

ACUVUE is also the most prescribed lens for all soft extended wear new patient fits, the company said. During 1989 ACUVUE captured over 86 percent of the disposable lens market.

The company also noted that its Vistamarc™ 58% and Hydromarc™ 43% toric lenses increased their market share 2.7 points during the fourth quarter of 1989.

Reviewing the dramatic growth of the company since the national launch of the ACUVUE Disposable Contact Lens in June of 1988, Vistakon's President Bernard W. Walsh cited the acceptance of ACUVUE by patients and eyecare professionals as the key to its success. "The convenience, comfort and visual acuity of ACUVUE have answered important needs in contact lens wear," he said.

"Further, we've responded to the requests of eyecare professionals to provide ACUVUE benefits to even more patients with our new daily wear, two-week replacement option.

Walsh added, "ACUVUE is also in full nationwide distribution of plus powers, making the monovision technique an excellent option for presbyopes who qualify for soft contact lens wear, a growing market as the baby boomer generation ages."

*Source: Vision Information Services, *The Contact Lens Report*, Health Products Research, North Branch, N.J. (4th Quarter 1989.)

ASCO Convenes Optics Conference

Faculty representatives from most of the schools and colleges of optometry were in attendance at a two-day workshop on optics held April 21 and 22, 1990, in Tucson, Arizona. Approximately 40 individuals participated in the meeting convened by ASCO and sponsored by Varilux with support from AIT, Logo Paris and Silor.

The meeting was opened by Varilux director of professional relations, Dr. Rod Tahrán. Ms. Lee Bayusik, executive editor of *Eyecare Business*, described the current competitive optical market as one in which good staff communications are critical.

Mr. John M. Young, director of quality assurance and technical affairs for Essilor of America, in a talk on Ophthalmic Liabilities, warned that one key to avoiding possible lawsuits is to keep scrupulous records. In a later session,

Young, speaking on the New High Index Plastics, said that chromatic aberration and scratch resistance were most commonly cited as main concerns, but that new scratch coats and correct selection of base curves can alleviate these problems. Mr. Dick Wohlever, director of educational services at Walman Optical, described new ophthalmic lens products, and Dr. Don Schuman, professor at Pacific University, encouraged humor and using models as effective teaching techniques for ophthalmic dispensing.

Mr. Jeffrey M. Wallish, national key account manager, AIT, unveiled a program whereby AIT will supply a complete finishing lab to a school upon request. At the end of the school year, the equipment will be sold to students or alumni at substantial price reduction with any profit returned to the school into the alumni fund or in the form of a scholarship.

Ms. Diana Downs of LOGO Paris identified characteristics of a quality frame. Dr. Michael Cho, of the University of Alabama at Birmingham, described building a successful dispensary in an academic environment. Mr. Steve Chance, director of communications at Varilux, spoke on how a school could utilize most fully a manufacturer's resources.

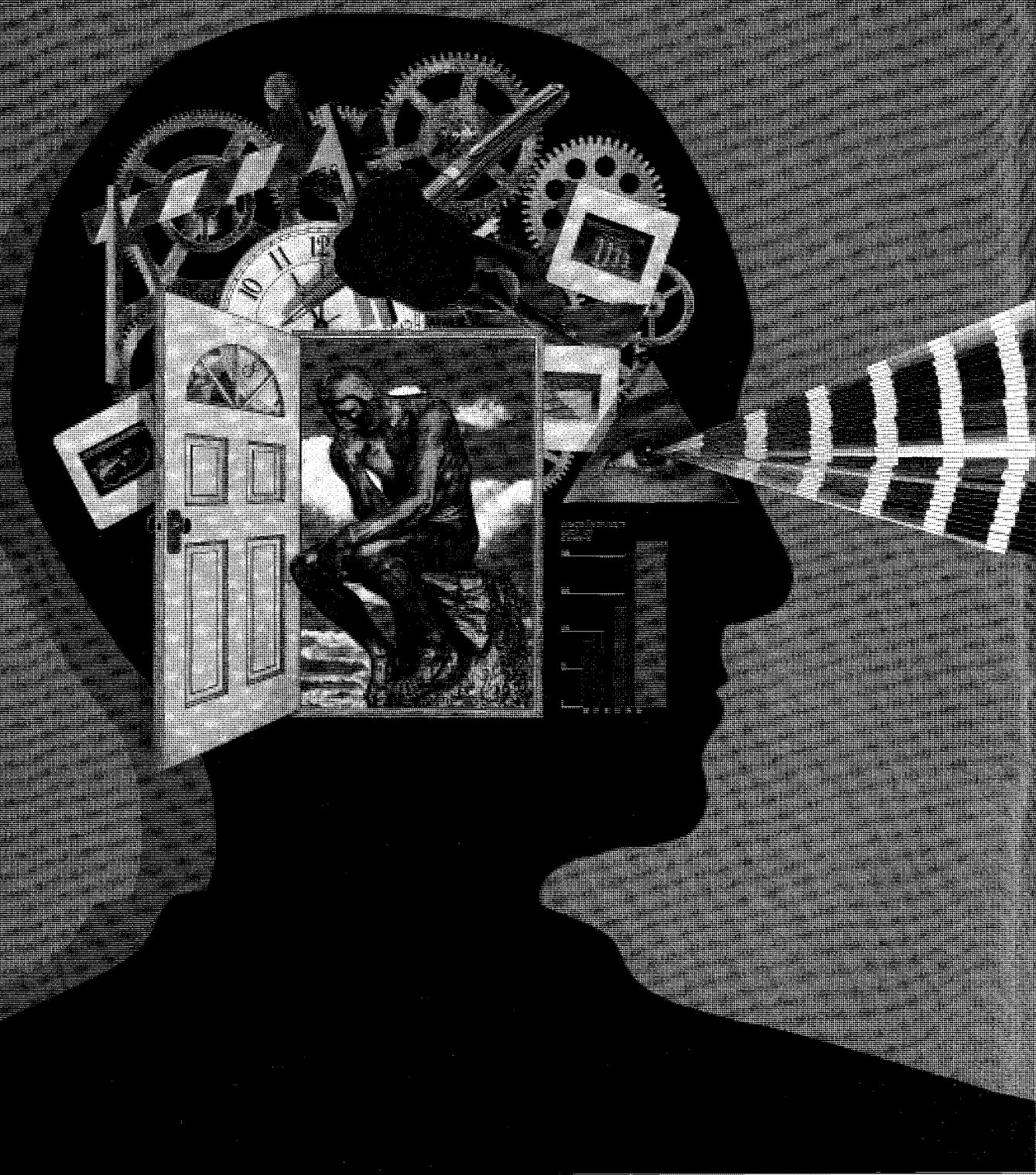
The second day of the workshop focused on a discussion of the optics and dispensing curricula by the faculty representation in those respective areas. The two groups separately reviewed course outline, the laboratory component, effective teaching techniques and the development of a curriculum model. At the end of the day a joint meeting was held during which each group reported its conclusions. A written report of the meeting will be circulated to all ASCO member schools for review and comment.



L to R: Front row (seated) Diane Downs, Logo Paris; Rod Tahrán, OD, Varilux Corp.; Lee Bayusik, Executive Editor, *Eyecare Business*. Back row (standing) Michael Cho, OD, University of Alabama; Jeffrey Wallish, AIT/Photocentron; Don Schuman, OD, Pacific University; Danne Ventura, FNAO, Varilux Corp.; Richard Wohlever, Walman Optical; John Young, Essilor of America; and Steve Chance, Varilux Corp. (photo courtesy of Varilux)

Teaching Clinical Reasoning

Optometry schools respond to the challenge of developing more effective methods for teaching clinical reasoning.



Cognitive Science Insights for Professions' Education

Ann Myers, M.S.

Introduction

Regardless of the profession—physician, lawyer, merchant chief, or optometrist—the goal of education in the professions is to produce competent practitioners of that profession. A competent practitioner is one who 1) has the knowledge and skills, 2) to deal with the problems encountered in the domain of practice, 3) at a minimal standard set by the profession, 4) and will continue to develop the knowledge and skills necessary to maintain competence as the domain of practice and/or the professional standards change.

In its attempt to produce competent practitioners, traditional education appears to have treated the four components of competence listed above as if their development followed the same sequence as appears in the definition and as if, consequently, education for competence must follow the following sequence. First, teach the student basic knowledge and skills. Second, expose the student to professional contexts in which he/she will develop strategies or use existing strategies to apply knowledge and skills in problem situations. Third, increase the frequency and complexity of application demands so that the student will develop increasingly sophisticated methods for dealing with those complexities until he/she demonstrates the ability to handle them at a minimum level of competence. Fourth, assume that after graduation, practice

demands will force the maintenance of competence even as the domain of practice changes or professional standards change. Much of traditional education for a profession, with its typical separation of basic knowledge courses and practice/application courses, fits this linear, sequential model.

*Knowing it for the test
doesn't mean you
know it for life.*

Such a model, while having a certain psychological appeal, increasingly has become a source of dissonance for professions educators for several reasons. First, knowledge and skills once acquired seem not to be retained with any reliability. "Knowing it for the test doesn't mean you know it for life." Further, the ability to use knowledge in ill-structured contexts seems not to follow necessarily from its acquisition in well-structured settings. "Just because you learned it in the

classroom doesn't mean you can apply it in the clinic." Finally, increased complexity of the situation does not in and of itself lead to increased competence of the practitioner either during or after training. One can "rise to the level of his incompetence." The Peter Principle is alive and well.

The purpose of this paper is to report on a few, though certainly not all, of the insights from cognitive science which can be brought to bear on professions education, in particular as these insights relate to those sources of dissonance from within traditional education mentioned above.

Knowledge: Acquisition, Retention and Application

The first note of dissonance sounded is this: knowledge and skills once acquired seem not to be retained or are not available at critical times. A corollary to this problem is the oft-heard complaint of students that what is taught in preparatory classes has limited utility for professional practice. Most of us could cite personal experience with having studied hard and learned well only to discover that the most critical knowledge is unavailable to us when needed in practice. We can also cite experiences of having studied hard and learned well only to discover that some other "critical" knowledge is absolutely useless in practice, leaving us with the feeling that our time has been wasted in the mastery of trivia. What is there about the relationship between acquiring knowledge and using it in practice that creates this gap?

Ms. Myers is on the faculty of the Southern Illinois University School of Medicine and coordinator of its Problem Based Learning Tract.

Useability Lies in Connectedness

As cognitive psychology began to emerge as a discipline, it brought with it what were then amazing insights. One such insight was that for knowledge to be useful, it must be understood, not merely recognized or recalled by rote. Greeno¹ summarized much of the early related work when he pointed out that along with *coherence*, or integrating via a common theme the various components of what is to be understood, and *correspondence*, or some mapping of what is understood onto what is supposed to be understood, understanding requires *connectedness*, or the relating of the new knowledge to the understander's other knowledge. Further, this kind of connectedness only happens through effort on the part of the individual.² The notion that the human mind acts merely as a tape recorder or video camera was dispelled. For information to become knowledge, it isn't merely recorded; it is acted upon to form interconnected frames of understanding, which have come to be referred to as schemata.³ These schemata, built in part through efforts directed at understanding prior encounters with knowledge and experience, become the framework for understanding future encounters.^{3,4,5} Glasser⁶ suggests that the use of a schema in the effort to understand is much like using and testing a theory. The situation-invoked schema is compared with observations and either accepted, rejected, modified or replaced if it fails to account for certain aspects of these observations. Further, individuals use default values associated with schemata to fill in information that is not available externally in order to round out understanding.³ Spiro⁷ further demonstrates that subjects will rely on the default values of preexisting schema even though they are in conflict with information that is available externally. So integral a part of the understanding process are these uses of schemata that subjects fail to distinguish between information they provide and information actually acquired from their observations. Further, information which fails to find a schematic fit may be ignored completely. The usefulness of knowledge, then, is a function of its connectedness, and connectedness doesn't just happen. It requires effort.

Connectedness is a Function of Context

As cognitive science began to shake off the restrictiveness of associationist paradigms, new insights regarding memory emerged. One insight reveals that

the context in which knowledge is acquired contributes to its connectedness; and the match between the acquisition context and the application context contributes to its memorability, and hence to its utility. Jenkins,⁸ in reviewing the evolution of theories of memory, observed, "What is remembered in a given situation depends on the physical and psychological context in which the event was experienced, the knowledge and skills that the subject brings to the context, the situation in which we ask for evidence for remembering, and the relation of what the subject remembers to what the (situa-

*The usefulness of
knowledge, then, is a
function of its
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connectedness doesn't
just happen.
It requires effort.*

tion) demands." It is important to note that "event" can be read as text, lecture, demonstration, etc.

So strong is the relationship between context and memorability that in the absence of connectedness to knowledge networks and in the absence of reliable mnemonics, memorability may hinge on the physical context associated with acquisition. A colleague reports that to ease apprehension about a certain section of qualifying exams which was to test long strings of definitions, she took vocabulary cards along with her for review while on her daily morning walk. Imagine her dismay two days before the exam when she discovered that she could only recall the definitions when walking—in the morning. Another anecdote: a small dispute has been raging in our institution between students and a basic science department. Students have requested that sets of slides similar to

those used when recognition exams are administered be placed in the library, making them available for review for the exam. The department argues that all slide material is given to students on microfiche, and that it is identical to the material displayed on the kodachrome slides. The slides would be redundant. But the dispute here is not one of whether or not the material contained in the slides and the material on microfiche are similar. All agree that the content of the two is identical. The students are merely acting on the realization that the nearer the match of acquisition context to application context, the better the chance of recall. It is little wonder that students in clinical contexts bemoan the fact that they have forgotten what was learned in the basic science classroom.

Enter the problem of knowledge escalation within almost every profession. To cope with this escalation, both teachers and students have altered the knowledge acquisition context by implementing economy strategies and in doing so have influenced the potential for knowledge connectedness. Teachers abstract, digest and condense, creating compactions of knowledge that are dispensed and subsequently tested. Students devise mnemonics and rehearsal strategies to aid in recalling these compactions for subsequent regurgitation. Of even greater concern is the tendency of students to actively constrain connectedness in order to better insure that the compactions remain intact. After a recent examination in a course which attempted to integrate clinical and basic sciences, students complained that there had been no indication as to which questions were from which disciplines, and without such identifying information, they were hampered in their memory searches! Over the course of the basic preparatory curriculum, students accumulate a capacity load of such compartmentalized knowledge pellets, much of which is held on to for some culminating event such as certifying examinations, then dumped or allowed to fade from memory. In a recent evaluation of a course particularly noted for this kind of teaching and evaluation, one student remarked, "We have no way of knowing what's important or what will be clinically relevant. If we did, we could hold on to that in some way, but since we don't and since we can't remember *all* of it, we just *forget* all of it."

It is important to realize that when information is learned through mnemonics, it is connected to that mnemonic; when information is understood, it is connected to the vast network of

understandings; when information is compartmentalized, it is disconnected and rendered virtually useless for application to new situations.

Knowledge: Reformation for Application

A second source of dissonance within traditional education in the professions is a concern that the ability to use knowledge in ill-structured contexts may not necessarily follow from its acquisition in well-structured settings. One widely held belief is that good problem solving and other intellectual operations reflect general strategies operating on whatever database of knowledge is needed, a fallacy Perkins¹⁰ refers to as the Comprehensiveness Hypothesis. He relates it to the Teachability Hypothesis: acquire the database; train the strategies and *voila*—the student is a problem solver. Application of these hypotheses to education has led to a plethora of programs designed to teach general problem-solving skills, programs which are significant in that little direct connection is made between the process of problem solving and the learning of cumulative domains of knowledge.⁶ Such programs are generally ineffective in developing in students skills which are transferable to new situations.

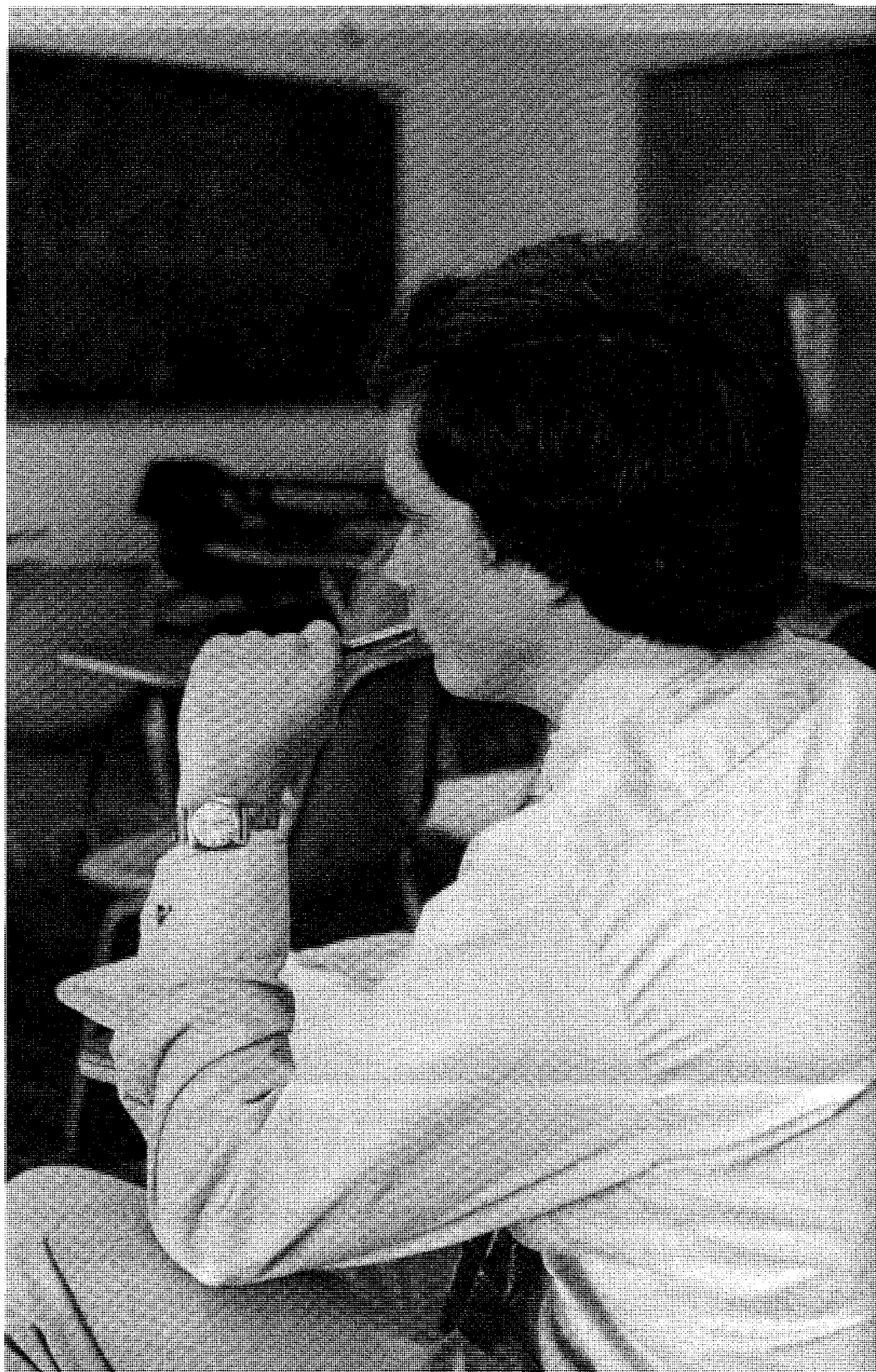
Application: Ill-Structured Domains and Ill-Defined Contexts

Another difficulty with approaches to theory and instruction with respect to problem solving is the well-defined nature of the problems used in research and teaching. These approaches seem to have grown out of the practice of forcing new theories of learning and cognition into old research methodologies. Problem-solving research has been done using rather simple, relatively well-structured tasks, typical of the memory experiment paradigm which preceded it.⁸ Perkins,¹⁰ in his critique of programs designed to teach problem solving, distinguishes between the well-defined, well-structured problems of research and teaching and the ill-defined, ill-structured problems of real life: "The isolated problem is a creature largely of the classroom. The non-student is likely to find himself or herself involved in what might be called projects . . . Complex, ongoing, indefinite in their requirements and open to diverse approaches, projects confront those involved with them with difficulties not represented in the microcosm of the isolated problem."

Another recent line of research in cognitive science has focused on inves-

tigating the understanding of complex concepts in ill-structured knowledge domains and the solving of complex, ill-structured problems.^{11,12} Spiro, et al.¹¹ contrast ill-structured domains of knowledge with well-structured domains. An ill-structured knowledge domain is defined as one for which it is impossible to formulate knowledge which will

explicitly prescribe the content domain's full range of uses because of a combination of its breadth, complexity, and irregularity. A well-structured content domain, on the other hand, is more "routinizable." The potential for formulating knowledge in a well-structured domain which will explicitly prescribe the content domain's full range of uses lies



within the realm of possibility. These authors argue that the two domains have significant differences, especially with respect to the application of preexisting knowledge to new situations. They propose that transfer in ill-structured domains is best promoted by facilitating the development of multiple interconnectedness between different aspects of domain knowledge, by selecting representative cases or examples which are multidimensional or can be viewed from multiple perspectives, and by encouraging a tolerance for various forms of naturally occurring complexity and irregularity. The process of applying such knowledge in new situations is more accurately described not as retrieval but as assembly. The problem solver operating in complex, ill-structured domains must be able to disassemble existing structures and assemble the resulting knowledge fragments into situation-specific schemata which themselves are subject to ready disassembly and reassembly, a characteristic termed cognitive flexibility. The appropriate approach to learning and instruction for such content domains centers around case-based presentations which treat the content domain as a landscape that is explored by "criss-crossing" it in many directions, reexamining each case "site" in the varying contexts of different neighboring cases, and by using a variety of abstract dimensions for comparing cases. "Information that will need to be used in a lot of different ways needs to be taught in lots of different ways."

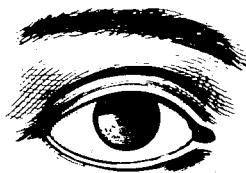
Problem-Solving in the Context of Clinical Practice: Ill-Defined Processes in Ill-Structured Domains

The knowledge base for professionals in clinical practice involves multiple intersecting, interacting, ill-structured knowledge domains. The application of this knowledge base to patient problems involves a process that has some unique characteristics.^{13,14}

First, in addition to calling upon domains of knowledge that are complex and ill-structured, the problem itself is ill-defined. Patients' problems do not present with all the relevant information in place. Initially there may be nothing more than a single complaint, as, "Sometimes I see double." From this point relevant information must be inquired after, a process which Barrows¹⁴ and others have noted is driven by hypotheses as to the patient's problem. A second characteristic of clinical problems is that they require reasoning from incomplete knowledge or information. At

any given point in time, the reasoning process centers around the testing of the practitioner's hypotheses, but these are based not on complete information but on present understanding, and in the absence of yet-to-be-discovered or never-to-be-discovered critical information. These hypotheses will be rejected or refined or added to as the practitioner adds additional information through the inquiry process. But rarely, if ever, does the practitioner have the luxury of a complete information base before making a decision.

A third characteristic of the clinical reasoning process is that there is rarely the option of "no solution" in the clinical context. Decisions must be made from uncertainty, based on the probability of correctness rather than the assurance of correctness. Compounding this is a fourth characteristic: the consequences of error are often severe. This adds to the constraints placed on the practitioner as he/she manipulates the variables in the process.



Problem solving in the clinical context involves a very complex, ill-defined process interwoven with multiple intersecting, interacting, ill-structured knowledge domains. What, then, is the process by which the practitioner develops competence and excellence in the field?

Knowledge: Culture and Context

We have already pointed out the concern among professions educators generated by the assumption that students who are placed in increasingly complex situations will automatically increase their ability to handle complexity, and further, that as the domain of practice and/or professional standards of practice change, practitioners will automatically accommodate that change while maintaining competence. This assumption might be called the "experience equals expertise" hypothesis. While experience is absolutely necessary for the development of expertise,¹⁵ it is not sufficient. Recall the old saw, "She doesn't have twenty years of experience; she's had her first year's experience twenty times." All of us can think of anecdotal incidents involving professionals who try to cope with increasing complexity by ignoring

the complexity in favor of a previously established routine or by opting out of the complexity by increasing the frequency of outside referrals. The development of expertise in complex, ill-structured domains now becomes a central issue for professions education.

Cognitive Flexibility and Expertise

The literature on the development of expertise, ably reviewed by Auble¹⁶ and Feltovich,¹⁷ suggests that expertise is not merely a matter of accumulating knowledge and strategies but of developing flexibility in reorganizing knowledge and strategies to fit changing contexts. Feltovich characterizes the differences between expert and novice behavior as follows:

1. Experts are action-oriented. They reorganize knowledge in the direction of increased value for doing the work of the field—for playing chess or bridge, creating computer programs, solving physics problems. Novices organize knowledge as well, but by features (proximity, similarity to other card games, etc.) rather than by function.

2. Experts can "turn knowledge around" so that, for example, they recognize not only how diseases typically present in a patient (concept-centered) but also patient cues that should lead the physician to think about a specific disease (cue-centered).

3. Experts have subordinated many task components to automatic processing, thus freeing up cognitive capacity for higher level skills such as thinking or integrating.

4. Experts engage in intermittent self-testing of their own understanding and practical solutions to problems, thus reducing errors, backtracking and blind alleys. In the vernacular, experts have not only a sound and flexible knowledge base and efficient and effective procedural skills, they are also top notch "metacogitators." Metacognition has been defined by Brown¹⁸ as self-regulating abilities including knowing what one knows and does not know, predicting the outcome of one's performance, planning ahead, efficiently monitoring time and cognitive resources and monitoring and editing one's efforts to solve a problem or to learn. Experts know what they know, what they don't know, what they need to know and how to find out what they need to know.

Hatano and Inagaki¹⁹ suggest that theories about expertise may be biased by the highly structured domains in which they have been studied, pointing out that the behavior of experts in ill-

structured domains may differ from that of experts in well-structured domains. They distinguish between routine expertise which thrives in well-structured domains and adaptive expertise which is essential in ill-structured domains. Routine expertise is marked by excellence in speed, accuracy and automaticity of performance, but notably lacking in adaptability to new problems. Adaptive expertise, as its name implies, becomes evident only in new situations. Speed, automaticity and even accuracy may no longer be appropriate criteria for evaluating performance when considering ill-defined problems in ill-structured domains. Expertise for ill-structured domains will demand a sound, flexible knowledge base characterized by multiple interconnections interwoven with a repertoire of problem-solving and reasoning strategies and monitored by an effective self-regulation system which can monitor for efficiency and effectiveness and make or suggest necessary adaptations. Previously it was suggested that experience is a necessary but not a sufficient condition for the development of expertise. Now we can propose that the nature of the experience, and the commitment of the individual to it, are critical factors. The development of expertise in complex, ill-structured domains begs for systematic encounters with the representative problems of such domains, a commitment to persist in their solution and guidance through the intricacies which they entail.

Knowledge in Action and Reflection

The issue of complexity and ill-structuredness, and consequently the issues surrounding the development of expertise, have recently taken on added dimensions with the introduction of the notion of situated cognition. This idea holds that it is too simplistic to suggest that knowledge merely be oriented toward action or applied to action. Rather, knowledge must be considered to be embedded in action. It is created and made meaningful by the context in which it is acquired, hence the term "situated cognition."^{20,21,22} This is a subtle, but significant point. It suggests that centering professions education in the context of practice serves not merely as a vehicle for students to learn about the professions but as an essential experience for *learning* the profession, for developing the complex, interconnected structures that orient the student to wise action. Donald Schon²³ has developed a model of professional practice which embodies this idea. He argues that most

of the decisions made or actions taken by professionals do not stem from a previously acquired rule or plan, but are generated through cognitive interaction with the context. The professional context itself participates in the interconnectedness of the concepts, skills and strategies needed to operate wisely within it. Schon further suggests that the development of competence in action stems from a second process which he calls "reflection in action," that is the ability to call upon past experience to make mid-course corrections without interruption to the action or to review a completed action for efficiency and effectiveness. This would suggest that the acquisition of knowledge, whether cognitive or metacognitive, from an ill-structured domain needs to take place in the professional context of its future application.

Brown, Collins and Duguid²² speak of this as "cognitive apprenticeship." They suggest that conceptual tools, like concrete tools, reflect the cumulative wisdom of the culture in which they are used and the insights and experience of the individuals who use them. To learn to use conceptual tools as professionals in practice use them, a student must enter the community of the profession and its culture as an apprentice to the cognitive processes and consequent decision-making of the profession. He/she must become a "cognitive apprentice." Education in the professions must provide situations in which "master" practitioners can take on "apprentices," modeling the problem-solving/decision-making processes required by the profession, coaching the apprentice toward wise action and finally fading from the process so that the apprentice ably assumes all the roles of the profession.²⁴

Conclusion

A number of principles have emerged from the cognitive science literature which address the concerns emanating from traditional professions' education. From these principles we suggest curricular structures which address the concerns by facilitating the implementation of the principles. Finally, we will look briefly and generally at how problem based learning embodies the themes developed here.

Addressing the concern that knowledge and skills acquired in the basic preparatory years are not available in the clinical or practice years, is the principle that the usefulness of knowledge is a function of its connectedness to prior knowledge and this connectedness

requires effort. Further, the context in which knowledge is acquired contributes to its connectedness; and the match between the acquisition context and the application context contributes to its memorability and hence to its utility. To maximize memorability and utility of knowledge basic to clinical practice, structure the curriculum so that knowledge is acquired in a clinical context.

Addressing the concern that the ability to use knowledge in ill-structured contexts seems not to follow necessarily from its acquisition in well-structured settings is this principle: Knowledge needed in clinical settings is complex and ill-structured, demanding cognitive flexibility for its application in new situations. Further, clinical problem solving qualifies as an ill-defined process because of its demands for case-construction, decision under uncertainty, the demand for action and the potentially serious consequences of error. To maximize the development of multiple interconnectedness between different aspects of knowledge while developing all aspects of the clinical reasoning process, structure the curriculum so that knowledge acquisition emerges from clinical cases which criss-cross the various knowledge domains. Present cases so that there is the greatest possible fidelity to reality incorporating *all* aspects of the clinical reasoning process. Incorporate into the educative process opportunities to explicate the relationship between the various clinical contexts and the emerging concepts as well as opportunities to compare cases on a variety of dimensions, building in multiple perspectives and the tolerance for naturally occurring complexity and irregularity.

Finally, addressing the concern that increased complexity of the situation does not in and of itself lead to increased competence of the practitioner either during or after training, is the principle that the development of expertise in complex, ill-structured domains requires systematic encounters with the problems representative of such domains, a commitment to persist in their solution and coaching through the intricacies which they entail. Further these encounters should embody all of the elements of practice, including the professional contexts in which they arise. To maximize the development of expertise in ill-structured domains such as clinical practice, structure the curriculum so that students are immersed in the context of the profession, apprenticed to master practitioners in the field.

Explanations and examples of the Problem-Based Learning Method are

contained in other papers in this journal. However, it seems appropriate to relate the objectives of problem based learning to themes developed here. Barrows²⁵ has suggested three objectives for problem based learning.

Objective 1: Structuring of knowledge for use in clinical contexts.

Objective 2: The developing of an effective clinical reasoning process.

Objective 3: The development of effective self-directed learning skills.

These three goals of problem-based learning are directly related to the themes developed here. The goal of structuring knowledge in a clinical context is based on the recognition that the accessibility of basic knowledge is essential to competent clinical practice. The intent of the goal is that basic knowledge emerge from clinical cases. The literature cited here suggests that that goal be further explicated to include a curriculum design which maps cases to be sure that they criss-cross the various knowledge domains.

The literature on the uniqueness of clinical problem-solving or clinical reasoning, of course, has direct bearing on Objective 2. This literature lends strong support to a curriculum design which requires that students engage in the processes of case building, decision-making under uncertainty, and decision-making under pressure, processes which are slighted in many problem-based learning curricula. The curriculum design should provide for incorporating opportunities to explicate the relationship between the various clinical contexts and newly emerging concepts and skills. This, along with providing for opportunities to compare cases on a variety of dimensions, and building in multiple perspectives and the tolerance for naturally occurring complexity and irregularity, falls into the tutor's domain.

Objective 3, the development of effective self-directed learning skills, is related to the literature on metacognition and the developing of self-regulation skills. This, too, falls within the role definition of the tutor who by externalizing the processes of self-questioning, planning, and evaluating, models self-regulation and coaches toward it.

The suggestion that to maximize the development of expertise in ill-structured domains such as clinical practice, students should be immersed in the context of the profession raises other issues that are not entirely unrelated to other themes addressed here. Collins and Frederickson²⁶ have proposed the notion of systemic validity with respect to evaluation. They define systemic

validity as the extent to which the test itself induces in the education system curricular and instructional changes that foster the development of the cognitive skills the test was designed to measure. For example if, in preparing for a test purporting to measure problem solving, students expend considerable cognitive effort in rehearsing and memorizing, that test has low systemic validity. They also point out that there is a cost involved in maintaining high systemic validity, a cost that may translate into the lowering of other forms of validity or reliability.

There is room for such a notion in curriculum design as well as in evaluation. If the goal of the educational system is to prepare the student for professional practice, then systemic validity for a curriculum might be defined as the extent to which activities in the curriculum actually foster the development of those

attitudes, concepts and skills that define competence in the profession. Immersing the student in the profession for which the curriculum is designed to prepare him/her might seem to be the *sine qua non* of professions' education. Here too, however, there is a cost which might translate into a decrease in uniformity of experiences across students, a decrease in quality of experiences for some students, and even an increase in fiscal costs to students. Themes emerging from this selective literature review might lead us glibly to suggest that the ideal curriculum consists of finding smart people and following them around. Awareness of the costs, of course, makes such a proposal ludicrous. This does not, however, preclude attending to the value of fidelity in the educative process. It may well be the key to the development of expertise in ill-structured domains. □

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Problem Based Learning: An Alternative to Traditional Education

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Abstract

A growing number of health care educators are concerned with the effectiveness of the traditional approach for educating health care practitioners. The problem based learning approach has been advocated as an alternative educational method for addressing many of the current concerns and for producing a more effective doctor.

Traditional Health Care Education

The traditional approach for educating health care professionals has been in place and producing practitioners for over 100 years. While some health care educators are satisfied with the outcome of this time honored institution, there are a growing number that suggest the traditional method needs serious modification or replacement.¹ What are the concerns, both perceived and factual, that have created this desire to consider an alternative to the traditional educational approach? Many of the concerns are embodied in a 1984 report entitled "Physicians for the Twenty-First Century: The GPEP Report," which stresses the problems of too much passive learning, too much emphasis on memorization and too little emphasis on developing clinical reasoning skills.² These problems are not confined to the education of medical doctors, but are common problems among all health professions. From the viewpoint of

clinical optometric educators, the perceived concerns often revolve around three general areas:

1. The student's long-term recall of preclinical information (both basic visual and biomedical) is often poor. When students are confronted with patients' problems, they often have difficulty recalling the basic underlying anatomical, physiological and neurological concepts and mechanisms that may be involved in or account for the patient's problem. Often this lack of recall interferes with the student's understanding of the source or etiology of the problem, and more importantly, with the potential treatment options.

2. The student's clinical reasoning process is often inappropriate, inaccurate or inefficient. Students often demonstrate a slow learning curve when it comes to developing diagnostic strategies, or logical thought processes that help organize the collection, analysis and synthesis of clinical data.

3. The student's self-directed learning ability is often lacking. When students are confronted with an unfamiliar problem, they are reluctant to seek the answers on their own. They tend to rely on clinical staff, which is good for the faculty's ego, but not necessarily an effective method for developing the lifelong skills students will need to stay current and competent in clinical practice.

Perceived problems in each of these areas have convinced many health care educators to reassess current educational practices. In addition, the student's development in each of these areas has a direct impact on the general

scope and responsibilities of optometry as a profession. As optometry solidifies its role as the primary vision care practitioner, the doctor's responsibilities are expanding, and subsequently the amount of information necessary to practice competently is increasing at an alarming rate. Evidence of this change both in the scope and complexity of vision care is reflected in the fact that there are now over 50 vision care journals that a practitioner can subscribe to on a monthly or quarterly basis.

Intended Outcome

What is the intended outcome, or product that we as clinical educators would like to see as a result of the four-year optometric curriculum? Both optometric educators and the public (I would think) hope that the schools and colleges of optometry are producing doctors capable of evaluating and managing patients with vision problems in an effective, efficient and humane manner.³ What general skills are necessary to produce a doctor with these characteristics?

1. A person with a broad body of knowledge, both basic science and practical clinical information.

2. A person with the ability to retrieve and apply the knowledge as part of an effective and efficient clinical reasoning process.

3. A person with self-directed learning skills which allow him or her to remain competent and effective throughout a professional career.

Interestingly, the general character-

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istics of an effective doctor parallel the areas that students have the most difficulty developing. The traditional educational method appears to be less than satisfactory in producing the desired outcome. How can optometric education speed up or improve the process of developing an effective doctor?

Problem Based Learning

A Problem Based Learning approach (PBL) has been proposed as an alternative method for addressing many of the problems above and for producing a practitioner with the desired characteristics.⁴ The principle of PBL is to give students a task or challenge as a source for learning, which is similar to a problem with which they will be confronted in their professional future. In health care education, learning results from the process of working toward the understanding and resolution of a patient problem. In this approach, basic science information is learned or reinforced within the context of solving a patient problem. This provides a "hook" or advanced organizer for the future use of the information.

Usually PBL is conducted in a small group format of five to seven students with a faculty member serving as the tutor. The tutor's responsibility is to facilitate and indirectly guide student learning by the use of non-directive questions and comments. The small group allows students to pool their knowledge and background, and stimulate each other's thinking through active discussion. The basic outline of the Problem Based Learning process is:⁵

1. Encounter the problem first. The students, prior to any didactic instruction in the area of the problem to be encountered (e.g., basic biomedical or visual science training), are confronted with the "problem" usually in the form of a patient's entering complaint, such as, "My vision is blurry at near." The intent of the problem is to serve as a challenge to the student's reasoning or problem solving skills and provide an organizer for their learning.

2. Problem solve and identify learning issues. The students brainstorm on the potential reasons for the patient's complaint, not only from a clinical perspective (patient may be presbyopic), but also from the perspective of what basic underlying anatomical and/or physiological dysfunctions are responsible for the patient's problem. To do this, students will need to develop an understanding of the normal anatomical

structures and physiological concepts and mechanisms that are involved. From this discussion, the students develop a list of learning issues, consisting of the unknown information or concepts involved in the problem. In the example above the student would need to investigate the anatomy of the eye involved in clarity of vision, the physiological mechanism of how the lens shape changes, the effects of age on that process, the clinical methods used for evaluating the patient's accommodative ability, analysis of the diagnostic results, and what management options are available to treat the condition. The skillful tutor guides the students through hypothesis generation, inquiry strategy and problem synthesis. This stage of PBL serves to develop those cognitive skills necessary for the clinical reasoning process and self-monitoring skills essential for identifying learning needs. Students are challenged to recognize situations in which information is needed to understand the patient's problem or to analyze the basic mechanism underlying the problem.

3. Self-study. The student takes time to investigate these new learning issues. In contrast to the teacher centered instruction of the traditional educational approach, where the instructor determines what information needs to be learned, this process of learning or investigation is self-directed by the student. While investigating each of these topics, the student would start to develop a search strategy for identifying the best resources for improving knowledge and understanding. Resources might take the form of books, journals, slides, video, faculty lecture or personal interaction. Students are then encouraged to bring to the group any resources that could be of value to the group.

4. Apply newly gained knowledge to the problem. The students would return to the patient problem armed with this additional information and start the problem-solving process again. The emphasis is not on the reporting of the new information, but on using the information in the context of initially solving the doctor's problem, of determining the etiology of the patient's complaint and then sequentially solving the patient's problem of "blurred vision." During this process the students would critique their prior performance and the value of the learning resources they had discovered.

5. Summarize what has been learned. The student should make a conscious effort to summarize or reflect on what has been learned and how it has

impacted their ability to solve the patient's problem. This critical step associates the basic science and clinical information within the context of the patient problem and improves the recall of this information in the future.

The PBL approach has been instituted in several forms: as a complete professional curriculum;⁶ as a parallel tract to a traditional curriculum;⁷ as an approach for departments; or as single courses.⁸ Optometric education has recently shown some interest in this innovative approach.⁹ Examples of PBL applied to single courses are illustrated in the following papers. The challenge to optometric education is to develop a sound educational approach to address the expanding scope and depth of the profession, while producing lifelong competent optometric practitioners. The PBL approach serves as a potential tool in accomplishing this educational challenge.□

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Implementing Problem Based Learning in the Didactic Curriculum

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Abstract

Teaching critical thinking and problem solving is considered an important objective for optometric education. One of the teaching alternatives that has been recommended as an effective approach to achieve these goals is problem based learning. Problem based learning, however, has primarily been used in curricula that are entirely problem based or in situations in which there is a very low student-to-faculty ratio. In schools and colleges of optometry, the student-to-faculty ratio is generally very high and there currently are no curricula that are entirely problem based. In this article we describe our experience in implementing problem based learning for a large class in a traditional, subject based optometric curriculum.

Key words: Problem based learning, patient simulation, clinical reasoning process, clinical problem solving, optometric education.

Introduction

Problem based learning is an innovative instructional method designed to overcome some of the shortcomings of the traditional lecture or subject based teaching approach.¹ In contrast to traditional education in which facts and principles are presented first, in problem based learning, clinical problems are

presented initially. One of the primary advantages of problem based learning is that it emphasizes and provides more opportunity for critical thinking and clinical reasoning.

If we accept the concept that teaching critical thinking is an important objective for optometric education and that problem based learning is one of the more effective approaches for achieving this goal, an important issue for optometric educators becomes implementation of problem based learning in the traditional, subject based optometric curriculum.

In this paper we discuss our experience at The Pennsylvania College of Optometry (PCO) in implementing problem based learning in a didactic course. We will outline the problems we have encountered and the solutions we have developed to make problem based learning a viable teaching approach.

Implementation in the Traditional Optometric Curriculum

Purist Approach

Purists² believe that if a school adopts the problem based learning (PBL) method it should ideally be an "all or nothing" approach, meaning that all courses in the curriculum should be problem based or subject based. For example, Barrows² feels that combining courses using the traditional lecture format with problem based learning leads to enormous difficulties. In such a double system there are contrasting

demands placed upon the students. They are expected to spend considerable time with self-directed learning, yet they must also attend traditional lectures. Problem based learning, in its pure form, requires significant amounts of unscheduled time.

In the "pure" PBL curriculum, students work in small tutorial groups with a faculty facilitator, meeting for a half-day session three times per week. The group might also meet once each week for a clinical skills session in which the students would learn the skills and scientific basis for routine history and optometric examination. This would be the only formally scheduled time for the students and there would be no lectures. A large part of the student's time, therefore, would be spent in independent study, pursuing learning issues either derived from tutorial sessions or self-generated. Some time also would be spent interacting with faculty members who act as resources for learning.

During the half-day sessions the groups would meet with their tutors and a simulated patient problem would be presented. The specific clinical problems simulated would be carefully designed to introduce the techniques of problem based learning and to provide a survey of the major concepts in each of the basic science disciplines.

We felt that this pure approach could not be realistically implemented in the curriculum at PCO because the faculty/student ratio is too high and the rest of the curriculum is subject based. We, therefore, developed a modified or hybrid approach.

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Development of a Hybrid or Modified Approach

The title of PCO's third year courses are Normal and Abnormal Binocular Vision II and III. The subject is the physiology, neurophysiology, evaluation and management of amblyopia and strabismus. These courses are each allotted 25 hours of "lecture time" over a 10 week period and 4 hours of laboratory time each week. Using the traditional lecture format we have been disappointed with certain results of our teaching efforts. Many of our stated behavioral objectives directly involved the concept of a student being able to solve patient problems. Our testing revealed, however, that while students successfully memorized facts and principles, their ability to apply these facts and principles to clinical problem solving was less than adequate. Our primary objective was to eliminate the use of the standard lecture approach and institute problem based learning in an attempt to improve critical thinking and clinical reasoning skills. The challenge was to do this with a class of 145 students, only two instructors, and in an environment in which these students also were taking three other lecture courses. Unlike the ideal PBL curriculum in which students have very little scheduled time and many free hours to do independent learning, at PCO the weekly schedule for third year students leaves them with very little unscheduled time. They are scheduled for four didactic courses, laboratories, and clinical care. Given this environment, we felt that we had to make several modifications and compromises from the ideal PBL approach.

We first identified the critical and necessary components that we would have to incorporate in our course to make it successful, but which would not require an increase in class time or faculty/student ratio. These components are:

- A patient simulator that inspires questions and independent self-directed learning.
- Methods to provide frequent feedback enabling students to identify and correct mistakes and deficiencies, and to maintain a sustained effort throughout the course.
- A presentation of learning resources in a way that allows students to quickly and efficiently access materials. This is necessary because students have less time to devote to a PBL course in a conventional curriculum than in a pure PBL curriculum.

We developed six essential elements

for our PBL course: the simulated patient problem of the week, weekly quizzes, a detailed set of course notes, large group class discussion of patient problems, small group discussion, and a problem based learning evaluation system.

Simulated Patient Problem

The essence of PBL and of the redesign of our course was the use of simulated patient problems as the primary stimulus for learning. This was a radical change from our former lecture approach. We presented the students with a simulated patient the very first week of the course and it was the students' responsibility to do the necessary reading and research to solve this patient's problems.

Previous research¹ has shown that for PBL to be most effective it is desirable for the simulated patient problem to have the following characteristics:

- The problem should be presented in a format that will help the student develop clinical reasoning skills.
- The problem should stimulate appropriate self-directed learning.
- The problem should have high fidelity, i.e., the process of solving the simulated problem should be as close as possible to working with a "real patient."

Optometric educators have traditionally used written case studies containing history, examination findings, diagnostic test results, and consultants' reports. This format is used in lectures, course notes and textbooks. However, this approach is so unlike the encounter with a real patient that it has limited value. Some of the problems associated with this traditional approach are:

- The format is unreal and abstract. There is no challenge to the skills of interview and examination.
- The student is not challenged to develop an initial concept or to generate early hypotheses because all the important data are provided.
- A basic truism about patient problems as they present to a clinician is that all the important information needed to solve problems is typically unavailable. In written case studies it is all available.

An alternative to working with the traditional case study is the use of patient simulations. Barrows² believes that the simulation should be as close as possible to the real situation in order to benefit as much as possible from the advantages of real patients. Many formats for simulating patients have been developed in-

cluding the use of live actors, written simulations, and computer simulations.

Our primary problem in initiating PBL was a lack of availability of patient simulators capable of meeting these criteria for optometric use. Therefore, we had to develop and adapt for optometric use techniques previously used in medical education. We now have two patient problem simulation methods available and we have used both in our courses,

The first is a simulation method called the Portable Patient Problem Pack or P4. The P4 format is a set of playing cards which can simulate any optometric problem. We have described this format in detail in another paper.⁷ The advantage of the P4 format is that it is portable, inexpensive and does not require any sophisticated equipment. The simulated problems can be created in a relatively short period of time and are easy to reproduce. There are some significant disadvantages to this format, however. The most important is "cueing." The user can easily see all of the available actions and outcomes as he works with the deck of cards. This makes the method less realistic. It is also difficult to score and evaluate student performance with the P4 simulation, particularly when the class size and faculty/student ratio are large.

We also developed a computer patient simulation method called Problem Based Teacher (PBT) that is based on the P4 approach. This technique allows students to manage simulated patients. Students choose from approximately 400 possible actions using key terms. Students interview the patient, perform examination procedures, and order special tests—all by selecting actions—until they formulate a diagnosis and treatment plan.

Currently, the outcome corresponding to each action is primarily summarized with text. The cover test, pupil evaluation and versions, however, are graphically displayed by interfacing PBT with another software program called "OSP" or "Ocular Motor Simulation Program." Instructors author new patients or actions by modifying text files with a word processor or authoring software. If other graphic representations of outcomes are necessary (e.g., an image of the retina, visual fields, anterior segment), the student is referred to a notebook containing illustrations or slides. PBT is described in more detail in another paper.⁹

This computer simulation program eliminates cueing and greatly simplifies the evaluation of each student's performance. Because of these significant

advantages we now primarily use the computer simulation.

In our restructured courses, all learning revolves around these simulated patient problems. The students are presented with cases from the very beginning of the course and must learn the information necessary to understand the underlying physiology and etiology of amblyopia and strabismus, evaluate, diagnose and treat each patient. It is important to remember that this is the very first learning experience for the students in the area of amblyopia and strabismus. They are faced with this particular patient problem and the only knowledge they have is that which they bring from previous personal experiences.

We used these simulated patient problems in several ways depending upon the objectives at any particular point of the course. In the early part of the semester our objectives were aimed at identifying the mechanisms or dynamics that are involved in amblyopia at an anatomical, biochemical, or physiological level. Later in the course the emphasis shifted to interpretation of test results, diagnosis and finally treatment of the patient's problems.

Four simulated cases were assigned each week and students were required to attempt at least one case, although they were allowed to attempt all four. Over the 10 week course they were required to complete six cases and meet certain predefined performance criteria. The cases were carefully selected and structured to inspire questions that were addressed in the assigned readings and in class discussions. The computer simulations provided little feedback to the students about their selected actions.

Feedback was provided in the large group and small recitation discussions of the simulated cases,

A local area network with ten computer terminals was available in our library and provided students with convenient access to the simulated cases. The software was able to track the activity of each student and enabled us to evaluate their generation of clinical hypotheses, problem solving approach, history-taking skills, selection and interpretation of tests, diagnostic skills and management plan. The students were told that a percentage of the weekly quiz would be based upon this patient simulation and that they would be responsible for discussing the simulation in class.

Weekly Quizzes

A significant modification from an ideal PBL approach was the use of structured reading assignments and weekly quizzes to encourage students to study our subject area and complete the weekly simulated patient problem in a timely manner. The weekly quiz was administered during the first class session of the week which was a one-hour time slot. The quiz was based on the patient problem of the week and the assigned readings from the course notes. The questions were carefully designed to lead to a discussion of key points. Each quiz consisted of 10 questions and the allotted time for completion was 20 minutes. Students were given the opportunity to ask questions for the first 15 minutes of the session, followed by the 20-minute quiz. The last 15 minutes were devoted to a review of the questions and a discussion of key issues.

Students were allowed to retain the questions for future reference.

Published Notes

Since we eliminated all lectures we felt that the students would benefit from some structure in their learning resources. In an ideal PBL approach there is typically little structure or assigned readings. Students are expected to learn to utilize the library and discover the most useful resources for a particular learning issue. This approach may work well with a student-faculty ratio of 4 or 5 to one but we were concerned about its practicality with a ratio of 70 to 1. We were particularly worried that students would be very anxious about this first experience with PBL. We, therefore, developed a very detailed, textbook-like set of notes which covered the topics of amblyopia and strabismus. Students were required to read specific assigned chapters each week.

In addition, students used our notes as well as other resources to answer questions generated by the simulated patient of the week. Thus, although students had a specific reading assignment each week, they typically were required to refer to other sections of the notes and other readings throughout the course to learn the information necessary for the weekly patient.

Large Group Discussion of Patient Problem

The second session of the week, a 1 and 1/2 hour time slot, was used for discussion of the simulated problem of the week. A very specific format was used to encourage students to participate in the discussion of the patient, to teach problem solving skills and help the students develop clinical reasoning abilities.

We utilized an approach described by Barrows and Tamblyn⁸ who developed a five-step model of the clinical reasoning process. They believe that five steps occur sequentially in any patient encounter. These are:

1. **Initial Concept Formation**—The initial concept is generated from the clinician's perception of the patient and the setting in which the patient is encountered.

2. **Hypothesis generation**—Very early in the patient encounter, the examiner generates approximately two to five hypotheses as possible explanations for the patient's problem.

3. **Search and Scan Activity**—After several hypotheses, the clinician searches for data through examination,

TABLE 1
Weekly Schedule

Tuesday am	A one-hour session consisting of 15 minutes of general questions and discussion, a 20 minute quiz, and a 15 minute discussion and review of the quiz.
Wednesday am	Patient case of the week is due. Students can no longer receive credit for a case after 10:00 am.
Wednesday am	A one and 1/2 hour session devoted to a large group discussion of the simulated case of the week.
Monday or Wednesday pm	A one-hour small group recitation session devoted to discussion of a second simulated case.
Independent study	Students were required to spend a minimum of one hour in the library completing the simulated case of the week.

laboratory testing or consultation for evidence that can be used to confirm or reject early hypotheses—a process is referred to as “searching.” “Scanning” describes the activity used to look for information which may indicate an overlooked problem, to fill in background information, and to increase confidence that nothing was overlooked.

4. Problem Formulation—As data is gathered, a formulation of the patient’s problem evolves which is based upon the information gathered to that moment. If one interrupts an experienced clinician during an evaluation and asks him/her about the patient’s problem, he/she will be able to verbalize a fairly concise description.

5. Closure—This occurs when the clinician feels that he/she has all the information necessary to manage the patient’s problem.

This approach can be used rather easily in a clinical situation or when there is a small student-to-faculty ratio. To utilize this approach with our large group of students, we divided the class into small groups of 10 students per group. These groups were assigned numbers and the students sat together with other group members.

The initial presentation of the patient was shown on an overhead projector and the students were asked to break for three minutes to discuss three to five initial questions that they would want to ask based upon the initial presentation. After this three-minute break we called upon students in a random manner to list and defend the group’s suggestion. Our role was primarily to encourage discussion among students and groups using various statements such as:

- Do you agree with what was just said?
- Why did you make that suggestion?
- If your hypothesis is correct, how can you explain this other information?
- Are there any other questions which might be helpful?
- Are there any other hypotheses which might explain the patients’ problems?

After agreement as a group on the actions or history questions which should be asked, we supplied the simulated patients’ responses to these questions. This process was followed by a three-minute break in which the groups were asked to generate an initial list of clinical hypotheses which could explain the patients’ problems based upon the initial presentation and history questions. Students were asked for their

hypotheses and were required to explain their thinking. They were again encouraged to disagree and defend their positions. Early in the course, an emphasis was placed on asking students to predict examination findings based upon their list of hypotheses.

Additional three-minute breaks were taken giving the students an opportunity to recommend additional interview questions, examination actions, special testing and consultations. After each break the outcomes of these actions were provided along with discussion of the significance of this new information.

Depending upon our objectives for the week, we were able to direct the discussion towards basic science issues, underlying physiological mechanisms, administration of test procedures, interpretation of test results, differential diagnosis and treatment.

Small Group Discussion of Cases

To overcome some of the shortcomings of the large student-to-faculty ratio, we utilized the assigned laboratory time for small group recitation. In these small group meetings we had a ratio of one faculty member to 10 students. Each student attended one, one-hour recitation session each week. During this time a new simulated patient problem was presented on the computers. After the initial presentation the students were asked to select three to five actions and then stop and develop a list of hypotheses to explain the patient’s problems. The facilitator proceeded to encourage

student discussion and interaction. The facilitator established specific objectives that were to be achieved within a set timeframe. An example of such an objective is, “Over the next three minutes I want each group to select three examination actions they feel are appropriate and predict the expected results based upon the information available to this point.”

Otherwise, the discussion was directed entirely by the students. This allowed the facilitator to oversee two or three discussion groups at one time. In small group discussions we were able to achieve 100% student participation in the recitation sessions, and there was a greater amount of student interaction than in the large group discussions.

During each semester one or two traditional laboratories were scheduled to familiarize students with clinical equipment and testing procedures for amblyopia.

Table 1 summarizes details of the weekly schedule.

Problem Based Evaluation System

When using a PBL approach the evaluation of student performance also must be modified. Typically tests are designed to assess students’ ability to remember facts and principles. In a PBL system, memorization of facts and principles is de-emphasized and critical thinking, problem solving and clinical reasoning are stressed. It is, therefore, inappropriate to evaluate students using the traditional multiple choice type test.

TABLE 2
Advantages and Disadvantages of PBL for Students

Advantages

1. Students encounter a patient problem before learning facts and principles and must ask relevant questions prior to the answers.
2. Students are actively involved in clinical reasoning process and learn to solve problems without a prior solution.
3. Students learn in context of clinical problems.
4. Students are actively involved in class.
5. Students keep up with material all semester.
6. Basic science information is presented in context of clinical problems.
7. Students must independently research and answer questions.
8. Students discuss cases and learn from each other.
9. There is a de-emphasis on memorization and an emphasis on problem solving and use of learning resources.
10. At the end of the semester students have less studying for the final.

Disadvantages

1. Students very uncomfortable at first.
2. Must work considerably harder in beginning of semester.
3. Overall increase in student workload.

Development of an alternative evaluation system was one of the major problems we faced. We ideally wanted to use a system similar to the new clinical National Board examination which uses a two-dimensional patient management problem format.¹⁰ Because of the high cost of producing small numbers of tests we were unable to use this approach.

We decided to use a multiple choice format for the midterm examination. However, the types of questions asked were designed to require problem-solving skills, hypothesis generation and other skills the students were learning in the course.

For the final examination we required the students to complete a simulated patient problem on the computer. These cases were similar to and based upon the cases students had worked with during the course. The software was able to track the activity of each student and enabled us to evaluate their generation of clinical hypotheses, problem-solving approach, history-taking skills, and selection and interpretation of tests. After completion of the simulated problem, students were required to answer questions about the underlying physiology of the patient's problems, reach a diagnosis and outline a management plan. Because only 10 computers were available, this evaluation was time consuming to administer and required two, full eight-hour days with two faculty members. An advantage of using this examination format and basing it on previous cases is that it was a strong inducement for students to work on the simulated cases throughout the course.

The weekly quizzes and performance on the weekly simulated patient problems were also used as part of the evaluation of the students. To compute a final grade the quizzes were worth 25%, the weekly simulated cases 25%, the midterm 25% and the final exam 25%.

Advantages and Disadvantages of PBL

Table 2 lists the advantages and disadvantages of PBL for the students. Students were initially quite anxious and negative about the course. They were faced with the need to learn how to use new computer software, weekly quizzes, the expectation that they had to keep up with the material, the need to participate in class and a requirement that they take responsibility for their own learning. The course, therefore, required a significant increase in workload for the student compared to previous encountered "lecture" courses. After several

TABLE 3
Advantages and Disadvantages of PBL for Faculty

Advantages

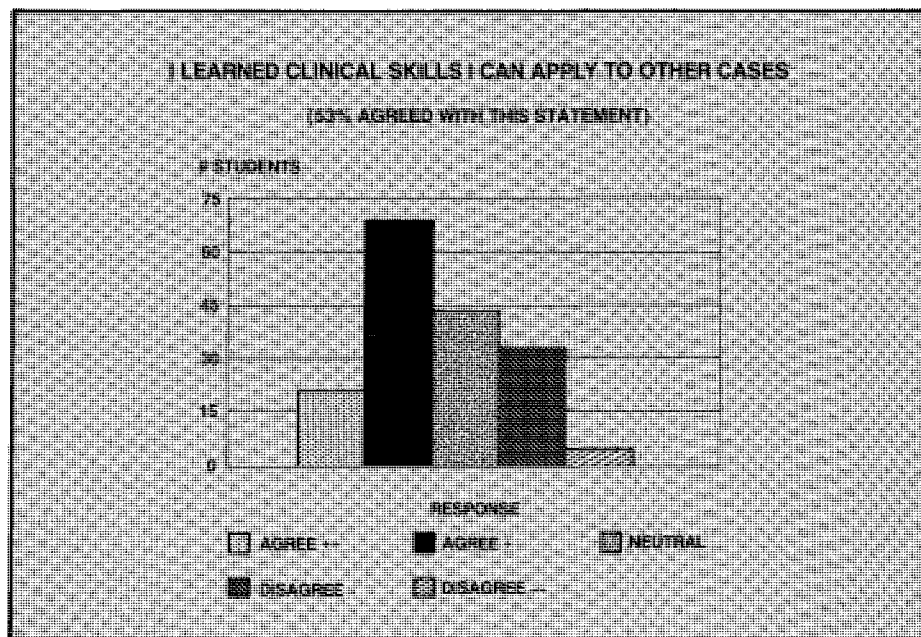
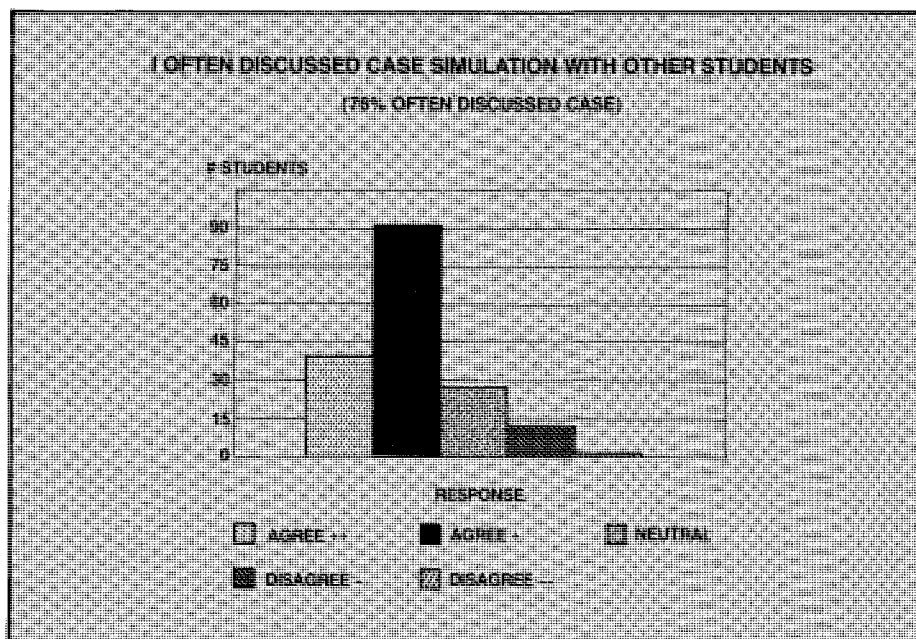
1. Teaching more enjoyable
2. Considerably more interaction with students
3. Better awareness of class progress

Disadvantages

1. During transition much more work than a traditional lecture format
2. Level of preparation must be higher
3. Students are anxious and uncomfortable if this is their first exposure to problem based learning
4. Final examination is very labor intensive

Figure 1a-b

Problem Based Learning Questionnaire:
Questions and Student Responses



weeks, however, as they adapted to these changes most students felt that they were learning more in the PBL format than in the traditional lecture. One of their major complaints was the significant amount of work they had to do in the beginning of the semester. However, students found that at the end of the semester they had to devote very little time studying for our course. This shift in workload from the beginning to the end of the semester complemented the pattern of work required in their other "lecture" courses.

The main advantages were that students were more involved in the learning process, and that learning took place in the context of patient problems. In our experience with the traditional lecture approach, students are generally not familiar with the material until they study for a test. They are, therefore, poorly prepared to either ask or answer questions in the classroom, and inter-

action with students is limited. In our course we found that students were able to ask excellent questions which indicated a high level of preparation. The other advantages and disadvantages we experienced are listed in Table 2.

In Table 3 we have listed the advantages and disadvantages that the instructor should expect when making the transition from lecture to PBL.

Student Reaction

As the semester progressed, we felt that students, in spite of their initial negative feelings, were adapting well and beginning to enjoy the new format. We administered a questionnaire at the end of the course, and the students' responses confirmed our feelings that the majority of students felt positive about PBL. In fact 75% of the students preferred the PBL approach to a traditional lecture format, 82% asked more ques-

tions on a weekly basis, and 72% felt that they looked up more material than in a lecture type course. The other responses to this questionnaire are illustrated in Figures 1a-b.

Summary

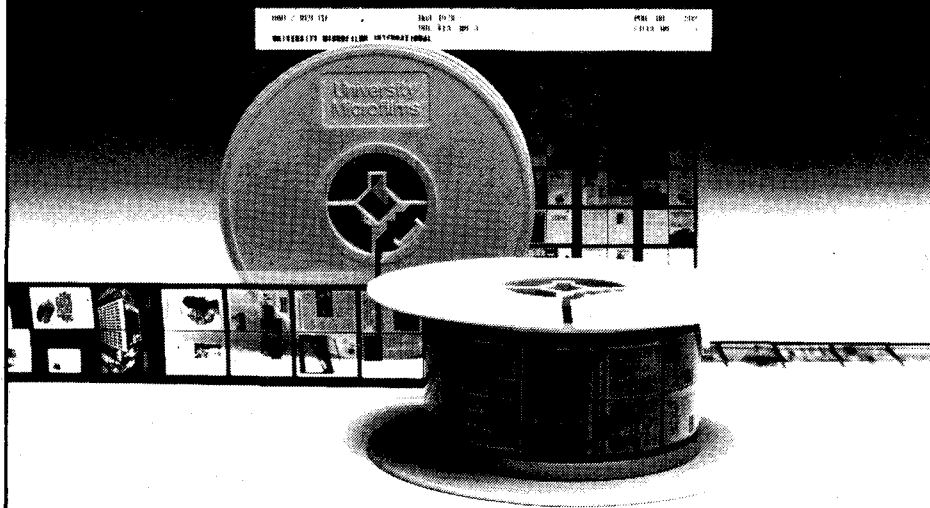
We have described our efforts to implement problem based learning in a traditional optometric curriculum in which the lecture is the accepted teaching approach. Among the problems we encountered was a large student-to-faculty ratio, the lack of patient simulators for optometric use, the need to develop new evaluation approaches, and initial student anxiety and resistance. We have described the modifications we made to overcome these obstacles.

Based on our positive experience with large group, problem based learning, we believe that PBL can be used very effectively, even in a curriculum that is primarily lecture based and even with a large class size. We encourage faculty at other schools and colleges of optometry to investigate and utilize this alternative teaching approach. □

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Teaching Clinical Reasoning

Daniel Kurtz, Ph.D., O.D.

Abstract

Optometric educators recognize the importance of critical thinking to optometry and therefore to the education of optometry students. Research on the cognitive processes of physicians indicates that they use three types of thought during patient care: (1) template matching, (2) deductive logic starting with multiple hypotheses, and (3) algorithmic logic. The three types may be used together or separately for different kinds of problems. Current research suggests that students can be taught these processes. Unanswered questions include how effectively an analysis of physicians applies thought processes to optometrists, and how well optometry students can learn the problem-solving strategies in the classroom or clinic.

Key words: clinical reasoning, template matching, deductive logic, algorithmic logic

Introduction

Optometry has emerged as a full-fledged profession, a discipline in which knowledge is applied to solve problems. This emergence of the profession has stimulated a corresponding recognition among optometric educators that their mission is to teach problem-solving skills, not just technical skills. Indeed, the Association of Schools and Colleges of Optometry has recently identified the teaching of critical thinking or clinical reasoning as a major objective of

optometric education by the year 2000.¹

Although great progress has been made in the teaching of technique through the use of manuals, videotaped demonstrations, structured laboratory exercises, and the like, much remains to be done in the area of teaching optometry students to solve problems.²

The teaching of problem-solving skills is a challenge for medicine as well as for optometry, and there are a growing number of studies on the subject in the medical education literature. The studies are of two types: (1) those that have investigated the cognitive processes of physicians in the act of making a diagnosis; and (2) those that have investigated the successes and failures of various educational approaches toward the training of clinical reasoning.

Studies of the clinical reasoning process

Three models

Studies of the cognitive processes of clinicians have revealed three principal models of clinical thinking. The first model designates that early in the patient encounter, and based on sparse information, clinicians generate a list of hypotheses or possible diagnoses to explain the patient's presenting signs and/or symptoms.^{3,4,5,6} This list is what is meant by the term "differential diagnosis" when used as a noun (for example, Roy's "Differential Diagnosis"⁷). Throughout the rest of the clinical examination the clinician tests and refines the list of hypotheses, rejecting some along the way, reinforcing others, possibly generating new ones, and

finally arriving at one or more diagnoses that explain the presenting signs and symptoms.^{8,9} The process by which this is done consists of only a few general cognitive processes, which the clinician uses over and over again in a circular or reiterative manner.

Clinicians, in analyzing specific patient problems, gather information in a manner depicted by decision trees, flow charts, or other representatives of the general group of models known as "algorithms,"¹⁰ according to the second model of clinical reasoning.

Such algorithms can sometimes be summarized in tabular form or in verbal form as a discrete set of questions, the answers to which determine the next question to be asked, and so on, until a single diagnosis is reached.¹¹

A third variety of clinical reasoning is recognition, template matching, or the "all-or-none model."^{12,13} According to this model, clinical information is gathered until it forms a pattern that matches a diagnosis familiar to the doctor, who responds with sudden recognition, an example of the familiar "ah ha!" experience.^{14,15} The presenting condition is then labeled and the diagnosis is made. The latter two varieties of clinical reasoning stress the process of diagnosis and are what is meant by the term "differential diagnosis" when used as a verb rather than as a noun.

Synthesis of the three models

Is clinical thinking circular, branched, or all-or-none? One possibility is that all of these models capture some part

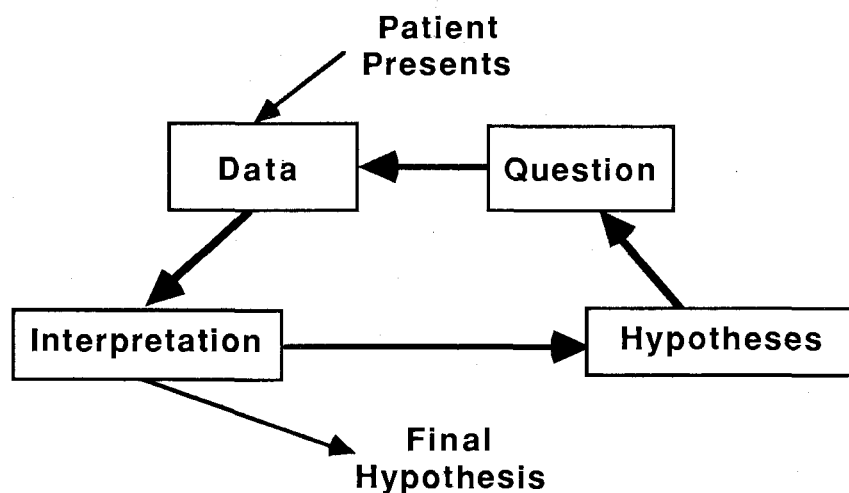
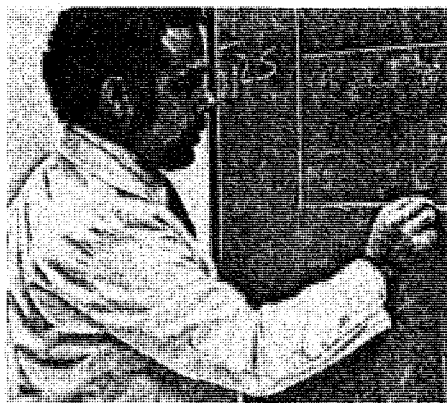


FIGURE 1.

Example of an iterative hypothesis or circular model of clinical reasoning, showing the relationship among four general processes. The doctor thinks through the four steps over and over until he/she has sufficient information to form a final hypothesis or diagnosis.

of the process.¹⁶ Thus, when clinical reasoning is described in terms of general cognitive processes, it is circular. However, such a general model cannot be used to solve a specific problem. Rather, in practice the clinician uses a specific algorithm which supplies the actual actions or inquiries that will be inserted into each of the general processes outlined in the circular model. Moreover, with each iteration through the circle of general



processes, the specific questions change and become more narrow, more specific, and more focused on a smaller and smaller set of hypotheses.

According to this synthesis, all-or-none recognition comes into play both at the outset and at the conclusion of the process. At the outset, recognition provides the initial list of hypotheses.¹⁷ For example, a patient may enter with a complaint of an eye that “feels funny,” has poor vision, or is red. Early in the encounter—regardless of what the

patient says—the doctor may recognize the problem as an example of the class of problems called “red eye,” and from this recognition he generates a list of hypotheses of possible causes (differential diagnosis as a noun). He then proceeds to solve the problem via his “red-eye algorithm.” The process (differential diagnosis as a verb) is concluded when there is a match between the data and the template of a particular etiology. The case is then solved, the diagnosis is pronounced, the management begins.

Alternatively, clinical problems may come in fundamentally different types, and each type may require a different strategy. Thus, template matching may work for one category of problem, algorithms for another, and so on. In addition, practitioners at different levels of expertise may use different types of processes than novices.¹⁸

Education in Clinical Reasoning

Are good thinkers born or can they be made? Given an enhanced understanding of clinical reasoning, can educators engender these skills in novice clinicians, or can students learn to think only through extensive clinical experience? Medical educators have attempted to address these questions, although only a few investigations have actually assessed the ability of students to engage in effective clinical reasoning after specific training in that skill.

Neufeld and co-workers found that, with training, students improved in the quality and appropriateness of their initial list of hypotheses (template matching).¹⁷ Beck and Bergman showed that students who had been taught to use a specific algorithm were more effective at solving certain problems than classmates who had received no such training.¹⁹ Finally, Wolf and others concluded that students could be taught successfully to apply the deductive, multiple-hypothesis approach to clinical problem solving.²⁰ Thus, medical students who have been taught specific problem-solving approaches have out-performed control subjects who lacked such training. Although the studies are few in number and have been limited to a single model of clinical reasoning, the results are promising.

The NEWENCO Experience

The faculty at the New England College of Optometry (NEWENCO) have initiated several attempts to train their students in clinical problem-solving. Although the effectiveness of these attempts has not been quantitatively assessed, they are presented here in the hope of stimulating others to create and evaluate similar methods. Such efforts at NEWENCO have been confined largely to the preclinical courses and to clinic.

In the preclinical courses, Optometry: Theory and Methods, a first-year course, and Advanced Optometry Theory and Methods, a second-year course, students receive specific decision trees for several problems, such as red eye (a simplified version of which is included here as Figure 2), visual field defects, Duane-White classification of binocular anomalies, and oculomotor disorders. Mastery of these algorithms is reinforced through homework assignments²⁰ and examination questions that can be solved readily by the application of the relevant algorithm. Students also are introduced to case analysis of simulated patients, and their skills are reinforced through homework assignments and class discussions.

Most lecturers in the preclinical courses also are clinical preceptors of second-year students in the primary teaching clinic. Having faculty serve both in the classroom and in the clinic assures reinforcement of classroom material in the clinical setting and promotes a strong sense of clinical relevance in the didactic setting. Continuity and feedback between the courses and the clinic are assured.

Within the clinical setting itself, the teaching of clinical reasoning has taken two main forms. First, NEWENCO now uses the Problem-Oriented Evaluation Matrix (POEM) to evaluate clinical performance. One of the key features of this tool is that it explicitly identifies reasoning and analysis as required, graded behaviors; it makes it clear to student and preceptor alike that the grade will be influenced by the student's ability to be a clinical problem solver.²² Since students have an almost uncanny ability to conform to the demands of their professors—if those demands are but clearly and unambiguously stated—it is reasonable to think that POEM will stimulate NEWENCO students to improve their clinical reasoning abilities. However, this supposition, reasonable though it may be, has not yet been empirically tested.

The second approach to stimulating the reasoning process within the clinical setting at NEWENCO was to redraft the examination recording form. On the new form, data which are usually interpreted together are recorded near to one another. On more conventional forms, data are recorded in the order in which the tests are done. Moreover, at critical points within the patient encounter, students are expected to stop their exam procedures and write down their tentative diagnoses.²³ A similar approach is being tried at the State University of New York.²⁴ The NEWENCO record also contains a problem and plan list as dictated by the problem-oriented record system.²⁵

Conclusions

Given the positive outcomes of teaching clinical reasoning to medical students and the importance of this subject to optometric education, the subject clearly deserves the increased attention of optometric educators.

However, more work needs to be done. Two questions come to mind as possible research areas. (1) To what degree are the studies of clinical reasoning in medicine applicable to optometry? Does the thinking behavior of optometrists mirror that of physicians? Berner¹⁸ has suggested that different problems within the field of medicine require different analytical processes; it is reasonable that optometry, too, has unique approaches to problem solving. (2) Only a handful of studies have shown that medical students can be taught clinical reasoning as a discipline. Can the same findings be obtained within the field of optom-

etry? If so, what are the optimal ways to train optometry students to think?

Despite such gaps in our knowledge, there is certainly good reason to move forward into the area of teaching clinical thinking, especially within the didactic setting.^{26,27} Indeed, faculty at a number of optometric institutions have already initiated coursework to train students

to master the clinical thinking process.^{28,29}

Within the clinical setting, it can be hoped that clinical preceptors will be able to use the encounter between student and patient to train their students in problem solving as they become more conscious of their own reasoning processes. □

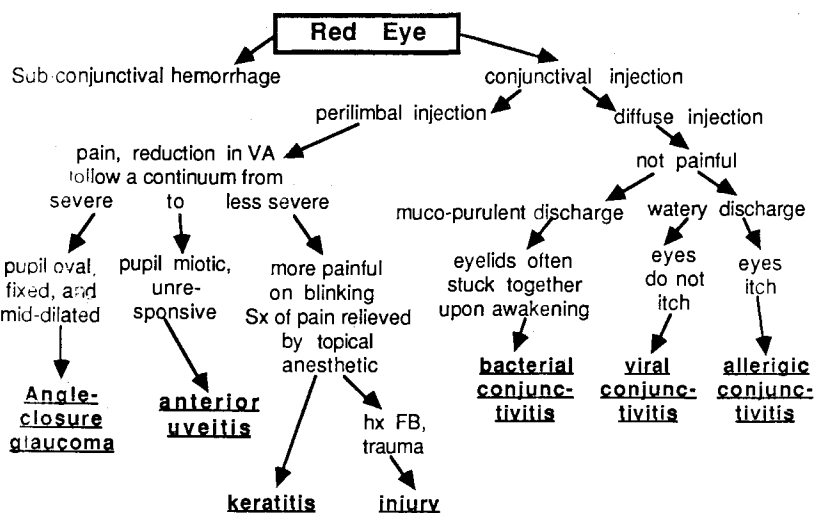


FIGURE 2.

Example of a simplified decision tree or algorithm of the type used with first-year students at the New England College of Optometry. Each branching point represents a particular observation or question.

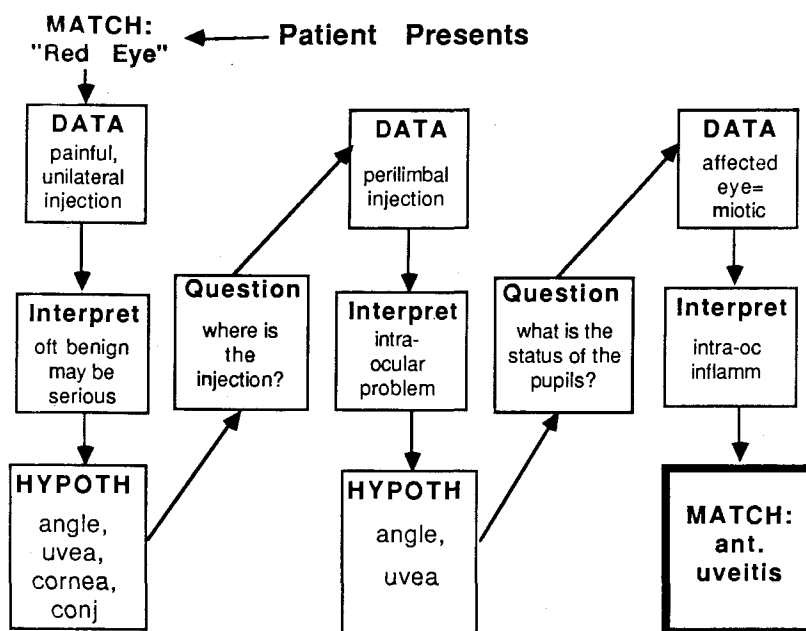


FIGURE 3.

Synthesis of the three main types of clinical reasoning. Template matching occurs at the beginning and at the end of the process. Specific questions and answers derived from an algorithm (Fig. 2) are entered into the general processes as outlined in the iterative hypothesis model (Fig. 1).

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ASCO's Window on Washington

Pictured at the national office in Rockville, Maryland, a suburb of Washington, D.C. are ASCO's staff: Pat O'Rourke, managing editor of the Journal of Optometric Education and manager of ASCO's sustaining member program; Elaine Nelson, secretary to the executive director, office manager and friendly voice on the telephone when you call ASCO; Robert Boerner, executive director; and Joanne Zuckerman, assistant to the executive director with responsibility for the annual survey of optometric education, the residency directory, the applicant status report, and other special projects. Joanne also is the liaison to the ASCO Council on Student Affairs.

Problem Based Learning in a Clinical Setting

Michael W. Rouse, O.D., M.S.Ed.
Eric Borsting, O.D.

Abstract

There is concern in health care education that preclinical knowledge is not being transferred to clinical problem-solving situations. A problem based learning approach (PBL), that emphasizes problem-solving and self-directed learning, was designed for third-year students entering their vision therapy clinic rotations. This paper will outline how this approach was used in a clinical setting, student and faculty responses to the new approach, and preliminary conclusions on the advantages and disadvantages of this approach.

Introduction

In the traditional health care education model the students complete preclinical training which provides a foundation of knowledge in basic and clinical science. Students entering clinical rotations are confronted with the need to develop their "clinical reasoning process (CRP)" as they encounter patients.¹ This mode of thinking is in contrast to the cognitive skills required for success in traditional didactic course work which emphasizes memorization of facts rather than problem solving. We have been concerned by the insufficient problem-solving skills in students entering the Vision Therapy Service, even though the students have had all the foundational basic and clinical science course work.

An additional concern is that students are first reluctant and then have difficulty researching issues for which they are

unfamiliar or perplexed as they encounter patients. Students tend to carry to the clinical setting a learning strategy that was used in didactic course work. For example, a student who is researching information about accommodative dysfunction might quickly review course notes or a text book for a definition without investigating the basic science principles underlying the diagnosis. Students tend not to use original sources and many times are unaware of what sources exist outside of lecture notes and a course text. Recent work suggests that traditional medical education which emphasizes lecture presentation may reinforce this type of learning style, referred to as a "surface learner."^{2,3} A surface learning is motivated by a fear of failure to complete the course and adopts a style of learning that emphasizes rote learning of the material required to pass the examination.⁴ This learning style would be counterproductive when a future doctor is no longer in the academic setting. In the practice setting self-directed learning is required to gather new information and knowledge allowing the practitioner to stay current and competent.

A problem based learning approach has been proposed as an alternative method to address these issues in the preclinical years. In this instructional method a learning environment is created where students either learn or reinforce basic preclinical information, principles and concepts within the context of solving a patient's entering complaint or problem. Barrows⁵ describes several objectives that are addressed by problem based learning: the structuring of knowledge for use in clinical contexts (SCC), the development of an effective clinical reasoning process (CRP), the development of effective self-directed learning skills (SDL), and an increased

motivation for learning (MOT).

Based on our primary concerns about problem-solving skills and the ability to do independent learning, we reevaluated our discussion format in the Vision Therapy Service. In the past, students had participated in a weekly discussion hour that attempted to bridge the gap between the lecture courses and the clinical application of the material. In this discussion format the students reviewed segments of cases that illustrated certain problems (i.e., accommodative insufficiency). This approach required the students to work independently for a short period of time and then the faculty member would facilitate a discussion about the results of the exercise. We perceived two major problems with this approach. First, we were becoming more disillusioned with a teacher centered format especially when students needed to shift from this style of learning as they were entering their clinical education.⁶ Second, this approach isolated various steps in the clinical reasoning process and, therefore, acted as an inefficient model for developing clinical reasoning skills.

The problem based learning method offered an alternative didactic approach that could be designed to address the specific areas in which students were struggling. The problem based learning approach was implemented in a clinical setting in the Vision Therapy Service at the Southern California College of Optometry for third year clinicians who have a weekly vision therapy rotation consisting of four hours (three hours for patient contact and one hour for discussion).

Educational Goals

Because we implemented this approach after the students had received

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their didactic course work, we expected that students would be able to address many learning issues with knowledge that they had acquired during their pre-clinical education. Our educational goals shifted from learning basic science information to implementing the objectives of problem based learning within a clinical context. Two general educational goals were decided upon that emphasized our primary concerns outlined earlier. First, help students to develop a better grasp of the clinical problem-solving process by using representative cases in binocular vision. Second, within the context of solving the patient's problem, promote and encourage students to become active independent learners. For the first educational goal the following behavioral objectives were developed:

- 1) Generate and prioritize a list of tentative hypotheses (clinical and underlying mechanisms) based on a patient's entering complaint.
- 2) Conduct a history inquiry that identifies: characteristics of the chief complaint, other associated symptoms, PEH, FEH, FMH, PMH.
- 3) Identify a sequence of testing procedures to rule in or out the tentative hypothesis.
- 4) Select the diagnostic test, being able to state why the test was selected and how to analyze the results.
- 5) Analyze the presented data stating the effect on the initial tentative hypotheses list.
- 6) Arrive at an accurate diagnosis, listing supportive data.
- 7) Outline a list of potential treatment options, being able to state the advantages and disadvantages of each option.
- 8) Design a sequential management plan to resolve the patient's SP's.

To address the second educational goal the following behavioral objectives were devised:

- 1) Identify and list "learning issues" as they proceed through the patient problem.
- 2) Identify potential learning resources that could be used to investigate the learning issues.
- 3) Investigate and report on the learning issues, stating the impact on the current patient problem.

Learning Experiences

Problem based learning uses simulations of patients' problems which allow the student to learn the basic and clinical science principles in the context of solving the patient's problem. Many methods exist for presenting a simulated

patient, such as P4 cards and simulated patients. We chose the problem based learning module (PBLM).⁷ A PBLM has all the information related to the patient: a complete case history, diagnostic tests, diagnosis, and management plan. The material is presented in a master action list (MAL) with all case history questions and diagnostic tests listed in an accessible manner. This arrangement allows students to encounter the patients as they would in a clinical setting; they are able to adjust their problem-solving strategy as they receive the relevant clinical information. In addition, the diagnosis and management plan of the original doctor is presented. The problems were chosen to illustrate the most prevalent conditions that the student would encounter in the area of binocular vision. All PBLM were based on real patients seen at the clinic, a point that was emphasized to the students.

The PBLM was presented in small discussion groups consisting of four students and a faculty member who served as the facilitator. The group was initially presented with the first patient's problem and was instructed on the problem based learning procedure which involves several steps: hypothesis generation, problem synthesis, self-study, re-evaluation of the problem, diagnosis and management. A chalkboard was used to record pertinent diagnostic information; one student was responsible for writing the information on the board. The board was divided into categories

based on the learning steps: hypothesis generation, tests and questions, and learning issues. An example of how this process works is illustrated in Figure 1.

The first step is for the group to generate three to five possible hypotheses that might account for the patient's entering complaint. For example, the problem used in the example discussion is that of a patient who gets a headache after reading for fifteen minutes. The group would be encouraged to prioritize the hypotheses based on their prevalence in the general population. Although this phase is difficult in traditional problem based learning, our students were already aware of likely diagnoses and were able to generate a list quite easily. However, as seen in Figure 1, students often used a particular diagnostic finding (i.e. high exo) instead of a diagnostic syndrome (convergence insufficiency).

After the hypotheses were generated, the group decided what information (diagnostic tests and case history questions) was needed to address each hypothesis; the group then began to gather the data from the PBLM. The role of the facilitator was to act as a mediator who helped the students develop an effective problem-solving strategy by meeting the behavioral objectives outlined earlier. The group initially gathered a case history related to symptomatology of the patient with standard clinical history questions. The facilitator asked the group how this in-

FIGURE 1
Example discussion session

HYPOTHESIS GENERATION

- Latent hyperopia
- Reduced accommodation
- Uncorrected refractive error
- High exophoria
- High esophoria
- Oculomotor dysfunction

TESTS AND QUESTIONS (PROBLEM SYNTHESIS)

- Frequency, onset, duration, relief of headache?
- Problem shifting focus from near to far?
- Previous eye exam?
- Current medication?
- Any allergies?
- VA's distance and near
- Cover test
- Retinoscopy wet and dry
- +/- 2.00 flippers, NRA, PRA, MEM
- NPC, phoria and BI, BO Vergences at near

LEARNING ISSUES

- Can poor saccades cause headaches?
- How to evaluate the accommodative system?
- How to determine if the problem is primarily in the accommodative or vergence system?

DIAGNOSIS AND MANAGEMENT PLAN

- Latent Hyperopia, Convergence Excess
- Prescribe +1.00 single vision and 10-15 visits of vision therapy

formation influenced the likelihood of the listed hypotheses. As the group gathered diagnostic test information, the facilitator needed to evaluate whether

the group understood the role of each test in making a potential diagnosis. For example, on the +/- 2.00 accommodative facility test the group must know

the normative data for the test, relate low results to symptoms, and be able to use the information to arrive at a diagnosis. From the results of the above testing and questions the group had a working problem list that assisted them in confirming the most likely diagnostic possibilities. The group's ability to assimilate the information from the case and arrive at a working list of diagnoses was a critical stage of problem based learning referred to as problem synthesis.

Many issues arise during the discussion group ranging from the inability to interpret the significance of test results to what information was needed to confirm or deny a diagnosis. One member of the group was given the responsibility for investigating a particular issue between discussion meetings (the group should decide among themselves who researches each learning issue). In the example case the group was unsure whether the accommodative or vergence problems were the primary cause of the problem. A student was assigned to research the issue between discussion sessions. This part of the learning process was meant to develop self-directed learning skills.

The person researching the learning issue then returned to the group and related the new information to the patient's probable diagnosis. This process allows the group to see the importance of the information and how it is needed to complete the clinical reasoning process. A reevaluation of the problem was undertaken and it was decided whether sufficient information was available to arrive at the diagnosis. The role of the facilitator was to encourage the group to justify its diagnosis with the symptomatology and diagnostic test information that was gathered. In the example case the group had to decide whether the patient had Accommodative Infacility or whether the Convergence Excess was causing the low findings on certain accommodative tests.

Finally, a variety of management options were reviewed along with the efficacy of each type of treatment. For example, in this case the group chose a single vision lens even though it would blur the patient's vision in the distance. This potential problem would become a new learning issue and have to be researched during the week if the group could not justify its treatment rationale. After this process was completed, the group was given the diagnosis and management plan that was arrived at by the original doctor who had seen the patient.

FIGURE 2.
Students' Response to Discussion Group

1) Working in this format was superior to a lecture format.	5) It was helpful to work in small groups.
40.3% Strongly agree	70.8% Strongly agree
48.6% Agree	26.4% Agree
4.2% Neither agree or disagree	1.4% Neither agree or disagree
5.6% Disagree	1.4% Disagree
1.4% Strongly disagree	0% Strongly disagree
2) The lack of guidance in the discussion groups was frustrating and impeded my ability to learn.	6) The group setting allowed me to express ideas without the fear of being judged.
1.4% Strongly agree	35.2% Strongly agree
11.3% Agree	52.1% Agree
14.1% Neither agree or disagree	7.0% Neither agree or disagree
57.7% Disagree	4.2% Disagree
15.5% Strongly disagree	1.4% Strongly disagree
3) Resources needed to answer learning issues were easy to find.	7) I enjoyed working with my classmates in this format.
11.1% Strongly agree	59.7% Strongly agree
41.7% Agree	33.3% Agree
27.8% Neither agree or disagree	2.8% Neither agree or disagree
15.3% Disagree	2.8% Disagree
4.2% Strongly disagree	1.4% Strongly disagree
4) It would have been helpful if the facilitator (the staff doctor) had given more direction on where to look for information on learning issues.	
6.9% Strongly agree	
33.3% Agree	
29.2% Neither agree or disagree	
25.0% Disagree	
5.6% Strongly disagree	

FIGURE 3.
Questionnaire (Self-assessment)

"I have an adequate understanding and application of information in the following areas:

	Strongly agree	Strongly disagree
• Identifying SP's	1 2 3 4 5	
• Visual Efficiency testing procedures	1 2 3 4 5	
• Identifying OP's	1 2 3 4 5	
• Developing the MPL	1 2 3 4 5	
• Stating syndrome diagnosis	1 2 3 4 5	
• Estimating treatment time	1 2 3 4 5	
• Developing a therapy plan	1 2 3 4 5	
• Sequencing a therapy plan	1 2 3 4 5	
• Specific therapy techniques in the following areas:		
• Oculomotor	1 2 3 4 5	
• Accommodative	1 2 3 4 5	
• Vergence	1 2 3 4 5	
• Sensory	1 2 3 4 5	

Results

In order to evaluate the success of the new discussion group format, a survey was created for both the facilitators and the students. In addition, the facilitators had meetings to discuss the new format. The student survey was designed to fulfill two functions: an evaluation of the students' opinion of the new discussion format and a student self-assessment of their progress in vision therapy (see Figures 2 & 3).

The results of the students' opinions of the discussion group were positive; 88.9% of the students felt this format was superior to a lecture format. Of interest is that 19.5% disagreed that resources to answer learning issues were easy to find; however, 40.2% felt that the facilitator should provide more direction on where to look. The results from the 1989 survey, and an earlier survey administered in 1983 when the older discussion format was used, were compared using the Mann-Whitney U test and the Chi-square test. Significant differences with both tests were found only for the first two questions ($p < .01$ for question #1 and $p < .02$ for question #2). The 1983 group felt more confident identifying subjective problems (SP's) while the 1989 group felt more confident administering visual efficiency testing procedures.

The response from the facilitators was not tabulated in a formal way due to the small numbers, but consensus was reached on three issues. First, the facilitators felt that observing students going through the clinical reasoning process helped them understand the areas in which students were having trouble diagnosing and managing cases in binocular vision. Second, students had a difficult time formulating a learning issue. They would know that there was a problem that needed to be addressed, but had a difficult time in formulating the actual question. Third, students had difficulty thoroughly researching learning issues, and applying the new information to the original patient problem.

Discussion

The problem based learning approach was implemented to achieve two educational goals: to have the students improve their problem-solving skills for diagnosing and managing binocular vision problems and, within the context of solving patients' problems, to have the students become active learners. The students' problem solving ability evolved as they solved consecutive patient problems. The group's initial

hypotheses and problem-solving strategies were often random. However, by exploring a variety of issues with the help of the facilitator, the initial haphazard approach gave way to a structured investigation of the patient's problem. The PBL approach allowed the student and the facilitator to uncover the weak points in the group's problem-solving process which was remedied through discussion and investigation of learning issues. The facilitators agreed that working with the students on problem-solving skills in this format was superior to the older discussion group method. Improving the independent learning skills proved to be difficult. Students accustomed to learning in an almost exclusively passive manner (lecture format) found it very difficult to shift to active learning. The group needed the help of the facilitator both to form learning issues and to find resources outside their lecture notes and course texts. This observation by the facilitators is inconsistent with the students' response on the questionnaire related to the ease of finding resources. Few students (19.5%) stated that resources needed to address learning issues were hard to find. In contrast to this 40.2% of students felt that the facilitator should provide more guidance on where to look for learning resources. In our opinion, students felt that their lecture notes and course texts were all that was needed to address an issue or that the facilitator should supply the needed information.

The lack of self-directed learning skills was not unexpected.^{8,9} In fact previous educators have created problem based exercises that help teach the development of self-directed learning skills.⁹ This issue was addressed when the second group of students entered the clinical rotation. First, the students were given a "pathfinder" list of core resources in binocular vision consisting of textbooks, and journals available in the library, and key words to help them find appropriate materials. Second, the authors chose a series of articles related to the cases which was made available in the clinic. This intervention altered the variety of sources students used when investigating learning issues. On surveys from the second group of students, a wider variety of resources were listed for researching learning issues.

We were concerned that students might not learn all the basic content knowledge and concepts that were reinforced in previous discussion groups. In fact this is one of the frequently raised criticisms of problem based learning.¹⁰ The results of the survey from 1989 and

1983 indicate that students felt that they had similar skills in almost all areas. The significance differences for the "SP's" and the "testing procedures" may have resulted from chance occurrences since we tested several hypotheses.

Finally, students had a favorable response to the problem based discussion group format. Several students commented that they felt challenged by "solving the problem" and felt that their problem-solving skills were improved by this method. In our opinion, students, in general, were active in the "problem solving process," but were hesitant in taking the next step of becoming a self-directed learner. This is not surprising given that a traditional lecture format allows little or no time to investigate an issue beyond what is needed to pass an examination. This is also consistent with research indicating that a traditional curriculum, which places a heavy emphasis on the lecturer transmitting the information, can encourage a surface learner type of strategy. Given that the scope of optometric practice is rapidly expanding, it becomes imperative that we train doctors who can utilize new methods and technology in the future. This process will be greatly enhanced if we provide our present students with effective learning strategies that can be used once they leave our institutions. □

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