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Problem-Based Learning

An Approach to Medical Education

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In *Problem-Based Learning*, Howard Barrows and Robyn Tamblyn address some basic problems in the learning of biomedical science, medicine, and the other health sciences. Students in most modern medical schools, especially in the basic science courses, are required to memorize a large number of "facts." Often the sets of facts they are required to memorize are chosen by the instructor based on what he or she knows and is familiar with. The sets of facts may or may not be relevant to medical practice. Furthermore, the student, a passive recipient in this approach, may or may not learn the facts in such a way that they are useful in future practice, regardless of whether the student is able to demonstrate on examination that his or her memory is good.

Problem-based learning has two fundamental postulates. The first is that learning through problem-solving is much more effective for creating in a student's mind a body of knowledge *usable* in the future than is traditional memory-based learning. The second is that the physician skills most important for patients are problem-solving skills, not memory skills. Most contemporary medical education provides students only limited opportunities to hone the general problem-solving skills with which their undergraduate education and life experiences have already equipped them. It consciously teaches little of the scientific method in biomedical problem-solving that is so much a part of good patient care. The problem-based learning approach, of course, has enormous utility for teaching in all the health sciences.

This book presents the scientific basis of problem-based learning in medical education. It then goes on to describe the approaches to problem-based medical learning that have been developed over the years at McMaster University. Barrows and Tamblyn are two of the principal creators of this "McMaster System." They have made a major contribution to the development of what will be the next historical stage of medical education. This book describes their work, in lucid and lively prose. We are proud to present it as the first in our "Springer Series on *Medical Education*."

STEVEN JONAS, M. D.

Preface

In this book the term *problem-based learning* refers to a very specific approach to education in medicine, supported by tools designed to facilitate a specific teaching-learning process, all described in the subsequent chapters of this book. Problem-based learning is not simply the presentation of problems to students as a focus for learning or as an example of what has just been learned. As described in this book, it is a rigorous, structured approach to learning that is tailor-made for medical education and based on considerable experience and research.

The questions that need to be considered in this preface are: Why is problem-based learning necessary? What evidence is there for its effectiveness? The answers have come to me through the series of experiences that lead to this book being written.

In 1963, I had been responsible for several years for a neurological clinical clerkship through which six or more third-year medical students percolated every four weeks. I became concerned that the usual faculty evaluations were not providing data that were truly helpful to the student. As a result, the simulated patient was developed and used as a standardized patient problem; this provided more data concerning student competence (Barrows & Abrahamson, 1964). It revealed that, although students had, for the most part, good techniques in performing a neurological history and physical examination, they seemed to have a paucity of basic knowledge that they could apply to the patient problem. This seemed paradoxical to me, as I had been closely associated with, and contributed to, the students' prior courses in neuroanatomy, neurophysiology, and clinical neurology. I knew that these students had been exposed to, and had passed, excellent, detailed courses.

This observation about students was shared by many on the faculty, leading to the recurrent, half-serious suggestion that the school ought to have an "inverted curriculum" where the students would have two years of patient exposure and then two years of basic science. Students thus could enhance

their learning and application of information, since the importance and relevance of basic science information could be perceived more readily.

George Miller (1962, 1978) has described on several occasions a study that documents the students' poor retention of basic science information. He asked sophomores, juniors, and seniors to retake the freshman examinations they had passed. It made no difference whether those students came from the upper or lower quarter of the class; none of them passed the retake. Miller has claimed that this retention of basic science information decreases at the same rate as has been shown for the retention of nonsense syllables. Levine and Forman (1973) went a step further and retested students about to enter their neurology clerkship. They were asked fifty questions that were chosen, because of their clinical relevance, from their first-year integrated neuroscience course. Almost two-thirds of the students received scores below minimum pass. Kelley West (1966) succinctly summarizes the fallacies of this traditional educational approach by pointing out that both logic and research prove it to be ineffective and, worse, inefficient.

Despite my realization that learning from patients and learning from books and teachers should go hand in hand, few substantial changes could be made in the curriculum of the school, despite endless efforts by a valiant but embattled group of faculty. As a result, I accepted the opportunity to take a sabbatical at McMaster University. My objectives were (1) to contribute to the efforts of a nuclear group that was designing a medical-school curriculum based solely on small-group, student-centered, individualized learning, and (2) to carry out personal study. During this sabbatical, my exposure to the teaching methods and concepts of Jim Anderson, a member of that nuclear group, provided me with considerable insight into the advantages of facilitatory teaching and the need to provide students with a packaged problem that would complement their work with simulated patients and real patients. This led to the development, upon my return from sabbatical, of prototypes for neurology "problem boxes" for clinical clerks. Students found these units to be engrossing, motivating, a challenge to their clinical problem solving, and a useful stimulus for reviewing basic science information.

To determine the best design for the problem box and to evaluate and facilitate the students' clinical competence, it became necessary to obtain a better understanding of how practicing clinicians dealt with patient problems. The simulated patient as a standardized problem seemed an appropriate tool for such a study. In 1969, I had the opportunity to work briefly with Shulman and Elstein, who were also embarking on a study of the physician's medical inquiry skills and wanted to use simulated patients (Elstein et al., 1972; Elstein, Shulman, & Sprafka, 1978). Subsequently, with the help of Kara Bennett, I carried out a study of neurological residents, clinical clerks, and neurologists (Barrows & Bennett, 1972). We utilized the simulated

patient and adapted Shulman and Elstein's technique of videotape recall (described in Chapter 2). I discovered that medical students and residents, for the most part, did not seem to think at all. Some gathered data ritualistically and then tried to add it up afterwards, while others came up with a diagnosis based on some symptom or sign, never considering possible alternatives. Subsequent experience with other students and other schools reinforced this uncomfortable observation and revealed even richer pathologies in thinking. Christine McGuire (1972) states that many medical schools would find that their graduates are wanting in clinical problem-solving skills, if they would use the appropriate tools to evaluate them. It seemed obvious to me at this point that students must learn, by working with problems, to develop appropriate problem-solving skills, and must make basic and clinical science learning more memorable and effective through their work with patients.

In 1971, I returned to McMaster and took advantage of what seemed to be an appropriate opportunity to develop the techniques of problem-based learning. My concepts appeared to fit well into their student-centered, small-group learning approach and seemed most relevant to their educational objectives (Neufeld & Barrows, 1974). A pilot program of totally problem-based learning was applied in the neuroscience portion of the curriculum, centered around some 22 problem boxes adapted from the neurology clerkship model. With the help of Donna Mitchell, my two-year experience with this approach was evaluated; its advantages seemed obvious (Barrows & Mitchell, 1975).

Evidence for the effectiveness of problem-based learning or "discovery" learning, has been in the literature for some time. Although the results of Katona (1940), Hilgard (1953), and Schmidt (1965), utilizing Katona's "card tricks," can be seen to be particularly relevant, they are not based on the use of patient problems. Moreover, any direct study of the advantages of problem-based learning in medicine requires comparison with a control group receiving more traditional educational experiences. This was not possible in the Barrows and Mitchell study. Tamblyn and I, however, had an unusual opportunity to attempt a study of the effects of problem-based, small-group learning on a small group of students within a more traditional curriculum and compare them with a similar control group. The experimental group demonstrated increased skills in problem formulation and self study, as well as a significantly greater motivation to seek clinical experience on their own (Barrows & Tamblyn, 1976a). On many subsequent occasions we have had the opportunity to engage student groups from many different schools in problem-based learning experience. Both the students and observing faculty are invariably impressed with the effects of this approach on both student motivation and learning.

In 1971, both Vic Neufeld and I felt that the inquiry studies of Shul-

man and Elstein's group and my study with Bennett could not provide generalizations about the problem-solving approach of the average physician and left many questions unanswered. With the assistance of Geoff Norman and John Feightner, we completed a study of 62 standardized patient encounters performed by a large number of general physicians selected at random. An analysis of extensive computerized data from this study allowed for a synthesis of the physician's problem-solving skills; this served as the model for the clinical problem-solving skills to be developed by medical students in problem-based learning (Barrows et al., 1978).

As a result, it was obvious to both Tamblyn and me that the problem boxes, as well as most other printed problem formats, were not challenging the student to develop all the important stages of the clinician's problem-solving approach. A specific problem was the linearity of these formats, which does not take into account the fact that the student should be free to take any action he wishes and in any sequence, as he can with actual patients, if he is to develop inquiry strategies. On a memorable day in October 1974, we watched a group of students become enthusiastically and totally involved in our first model of what has become known as the "P4," hastily written out by hand on various colored file cards. We were subsequently supported by a contract from the National Library of Medicine (No. 1-LM-6-4721) to produce and evaluate this format of problem-based learning units for neuroscience teaching. Rimoldi's (1973) prior work with a more limited version of a similar tool indicated that the student's problem-solving skills could be analyzed by this approach. Tamblyn's formal evaluation of this format with medical and nursing students suggested that this tool can be used by students, allows them to analyze and develop problem-solving skills, facilitates appropriate self-directed study, and, in addition, seems an attractive, motivating format (Tamblyn & Barrows, 1978).

Work with faculty and students from many schools in developing problem-based learning approaches has continued to demonstrate their effectiveness in helping students to develop scientific thinking about patients' problems and to acquire both basic science and clinical information in a manner that ensures retention and transfer to the real-life task of the clinician. Much more needs to be done to enhance the value of problem-based learning, to evaluate its strengths and weaknesses, and to give faculty and students skills in its employment. It is hoped that this book will make a contribution in this important area.

I would like to acknowledge my indebtedness to Steven Abrahamson and Jim Anderson for the education I have received working with them. The help I have received from Vic Neufeld, Geoff Norman, and the many others in the Program for Educational Development at McMaster must also be acknowledged. The continual support I have received working with Robyn

Tamblyn, carrying out many of the difficult but necessary aspects of work and study in problem-based learning, has allowed for a quantum jump in productivity. She has provided new insights into and techniques for problem-based learning. More importantly, she has worked to make this approach both relevant and available to other health professions, particularly nursing. In her own work, she has shown how effective problem-based learning can be for interdisciplinary education in health sciences; this is a most needed but, as yet, relatively unexplored area in health education. I also want to acknowledge the more-than-moral support I have received from my four daughters and from my wife, Phyllis. Not only have they tolerated my many trips around the countryside to work with teachers and students interested in problem-based learning and my eternal reading and writing at home, but they have provided constant encouragement and help. Lastly, both Robyn Tamblyn and I owe a great debt to Pearl Dodd, who has proofread, critiqued, and typed the manuscripts for this book countless times.

HOWARD S. BARROWS

For the purposes of clarity, this book has been written with a major focus on the experiences of problem-based learning in medical education. In reading this text, it is important to keep in mind that this teaching-learning format is both relevant and appropriate for the education of other health professionals (nursing, physiotherapy, occupational therapy, and so forth). The common factor among these disciplines is the need to actively apply knowledge to the assessment and care of patients and the ability to continue to identify areas where further learning would enhance or improve the practice of these skills. As in medicine, problem-based, student-centered learning is the most efficient method of simultaneously developing knowledge, reasoning skills, and study skills. Disciplines will differ in the problem situations they select for their students and the goals and expectations for patient assessment and care, but the basic learning method can be the same.

There are added benefits when the problem is used as the focus of study in team learning. The relationship between disciplines can be seen clearly and developed around an appropriate focus, the patient. Common and unique professional knowledge and skills can be observed and discussed and, in our experience, a more efficient and effective team relationship is a natural result.

ROBYN M. TAMBLYN

Introduction

Over the last few years, we have worked with faculty and students of many schools in North America, Holland, England, and Japan, in workshops devoted to problem-based learning, the use of simulated patients, and the design of problem-based learning units. This book has evolved from many requests for a basic text in the area. It represents both an update and an enlargement of a brief monograph we designed for faculty and students, to orient them to problem-based learning. It incorporates what we have learned from the experiences and studies described, as well as the many ideas and comments we have gained from our various faculty and student interactions.

We have attempted to avoid jargon as much as possible. We offer no apologies for the fact that many of our educational researches and examples are in neurology; this is our field of expertise and our involvement in problem-based learning was due to attempts to accomplish more effective learning in neurology. It is our hope that the reader will see how the concepts and techniques described here can be useful in his or her teaching or learning, regardless of the subject matter. In an attempt to allow faculty and students in all varieties of teaching situations to see the relevance of this approach to their own needs, this text tries to avoid using one educational level, class size, or teacher-student relationship wherever possible. This may seem confusing to the reader unless it's appreciated that we want to concentrate on the *processes* involved in both student learning and the interaction between teacher and student, not on the particular student, teacher, or setting.

Although we have opted to use the male personal pronoun out of convenience, it is intended that she or he and her or his are completely interchangeable.

The structure of problem-based learning as a technique, the rationale for its use, the necessary tools, the teaching skills required, and techniques for evaluation will be described in considerable detail. It is our hope that the reader will find useful ideas in this book that can be expanded or adapted to meet his or her needs.

Definition of Terms

A brief definition of some terms seems in order here. Although most terms are defined in the context of the book, these few could seem mystifying or misinterpreted without comment at the outset on our specific use.

Teacher: This refers to anyone responsible for the education of students, for example, full-time faculty, part-time faculty, practicing physicians, other health professionals, or other students.

Students: This refers to anyone engaged in problem-based learning who wants to gain knowledge and skills, including medical students, interns, residents, physicians, nursing students, nurses, and so forth.

Clinician: This refers to anyone evaluating a patient problem, such as a physician, student, or nurse.

Diagnostic process: This refers to the analytical or evaluative process aimed at determining the cause or nature of a patient problem (as contrasted to therapeutic processes concerned with management or treatment). It does not refer to arriving at a specific or refined “diagnosis” or “differential diagnosis,” which is often neither possible nor necessary.

Action: This term, for writing convenience, refers to any of a variety of actions, cognitive or physical, made by the clinician in his evaluation and treatment of the patient. Actions include asking questions of the patient, examining the patient, ordering laboratory or diagnostic tests, requesting consultation, treating the patient, talking to relatives, asking for patient records, and the like.

Problem-Based Learning: Rationale and Definition

Learning from problems is a condition of human existence. In our attempts to solve the many problems we face every day, learning occurs. In looking for offices in an unfamiliar building, or addresses in an unfamiliar town, we eventually find our way. In filling out income tax statements, learning occurs, just as in trying to find out why the car won't start. Although we may not be consciously aware, these problem situations are all learning experiences that are providing us with information and knowledge that we can apply to future problems. The more opportunity we have to use this information in our day-to-day activities, the more ingrained and unforgettable it becomes. We may recall occasions when we have provided a friend or colleague with very helpful and even sophisticated information about a problem he is attempting to solve. Although that information may seem to have just "popped" into our mind as our friend attempted to solve his problem, a little reflection will reveal that we acquired it from our own experience with a similar problem. No doubt, problem-based learning is the basic human learning process that allowed primitive man to survive in his environment. Facts related to us by others or information we have read ourselves rarely seem to have the tenacity of the information we have gained from our own daily confrontation with problems. It would be safe to say that the great wealth of information we possess in our memory banks has remained there as a consequence of having worked with problems we have been faced with in such life situations as school, work, social situations, and our hobbies. Problem-based learning is the learning that results from the process of working toward the understanding or resolution of a problem. The problem is encountered *first* in the learning process!

There is nothing new about the use of problem solving as a method of learning in a variety of educational settings. Unlike what occurs in real-life situations, however, the problem usually is not given to the student first, as a stimulus for active learning. It usually is given to the student after he has been provided with facts or principles, either as an example of the importance of this knowledge or as an exercise in which the student can apply this knowledge.

Education as a Teaching Skill

Medical teachers will agree that medicine is a profession that requires, as a principle skill or capability, the lifelong ability to work through difficult and often unique patient problems. Despite this, the potential value or relevance of problem-based learning is not considered by teachers in their headlong rush to expose students, during their brief years of formal medical education, to more and more of the ever-enlarging and complex body of important concepts and facts in the basic and clinical sciences. In fact, the careful design and development of better educational methods, or approaches to medical education, is usually given a low priority by those involved in medical education. The reasons for all of this may be easy to understand.

Characteristically, teachers responsible for both the design of medical educational programs and for teaching the students in these programs, have other, more demanding responsibilities, usually in the areas of research and clinical service. Each member of a medical faculty has spent many arduous years gaining the knowledge and skills necessary to successfully carry out tasks in research and patient care. Few have taken the time to gain any specific or formal preparation to aid them in carrying out their responsibilities in medical education. While this is considered acceptable, medical schools would not tolerate such an amateur status in those responsible for research or patient care.

Without a background of specific studies or experiences in the applied sciences of education, medical faculty must draw upon their past experiences as students as a model for their own concepts and behaviors regarding education. This is shortsighted, however, since these faculty are responsible for the education of large numbers of students who will become the future providers of medical care and research. In the long view, as faculty, teaching should be their greatest responsibility. The fact that they are faculty in a medical school should indicate that education is a primary task. The reasons for this paradoxical situation are a matter of history and reflect the reward system used in medical schools, where faculty development in education is not encouraged. There are few schools who would put the education of students as

their highest priority, or who would allow faculty promotion and remuneration to reflect educational knowledge and skills equal to or above research and patient-care productivity. Nevertheless, if medical faculty would apply to the education of students the same skills of inquiry, reasoning, and treatment design they use in patient care and research, their amateur status in education would soon disappear and students would profit.

This perspective provides the rationale for this book, which was designed as a guide to medical education as an applied science, for those medical teachers who are interested in investigating better ways to prepare their students for the tasks they will have to perform as physicians. It is also intended that the approaches described here will be useful to other health science disciplines. To this end, the authors have drawn upon their additional experiences with nursing, physiotherapy, and social work students, as well as faculty in both unidisciplinary and multidisciplinary learning situations. The thesis of this book is that problem-based learning represents the appropriate educational method for medical students if their educational needs are considered from a logical or scientific point of view.

The Objectives of Medical Education

A basic concern for any educational program is whether or not the teaching or learning methods presently in use are appropriate to the outcomes expected of students. This is the same question that has to be answered in selecting a treatment plan for a patient or in choosing an experimental research method. There is a wide variety of teaching-learning options; the choice depends on the desired outcomes, which are the objectives of medical education.

Since the medical student is to become a physician, the expected outcomes can be identified by defining the tasks a physician is expected to perform competently. In the authors' opinion, the principle requirement of any physician, implied by the M.D. degree, can be stated as follows: *The physician should be able to evaluate and manage patients with medical problems effectively, efficiently, and humanely.*

Some of the terms used in this statement need to be elaborated so that the range of competencies assumed can be appreciated better.

Evaluate: This term encompasses a variety of subskills, such as the cognitive skills of clinical reasoning or medical problem solving, as well as interview, physical examination, and interpersonal skills.

Manage: This term implies skills in the selection and application of appropriate therapeutic interventions, such as medication, surgery, counsel-

ing, rehabilitation, and patient education in acute and chronic conditions. Clinical problem-solving or reasoning skills also are involved in this activity.

Patient: This term refers to anyone who either directly requests the physician's services or is referred to the physician for an identified or suspected health problem.

Medical: This term refers to the specific component of health care that belongs to the physician. It recognizes that the physician is a member of a team with many specialists, including nurses, rehabilitation therapists, psychologists, nutritionists, social workers, and so forth. Psychiatry is considered a medical discipline in this definition.

Effectively: This term refers to the accuracy and appropriateness of the physician's evaluation and care of the patient. The patient evaluation should be as precise and adequate as the time, urgency, and data available from the patient allow. The management of the problem should be appropriate to the particular patient and his particular problem.

Efficiently: This term implies an appropriate use of time and costs. The physician should not spend an hour with a problem that should only require fifteen minutes, nor should he use hundreds of dollars on laboratory tests and investigations when a less expensive workup would suffice. This definition also refers to his use of medical facilities and other health professionals.

Humanely: This term requires that the physician should be concerned about the patient as a person and not as a medical problem or disease. His evaluation and management should reflect an awareness of the patient's cultural, familial, economic, and psychological needs.

This task statement for the physician can be adapted and modified to be appropriate for such particular sectors of medical practice such as primary care, secondary care, general or family practice, or specialty practice. It serves, however, as a useful orientation to the behavior we would like to see medical students demonstrate upon graduation.

The next important task for the physician relates to his medical career. No matter where the physician finds himself working in medicine, which is a vast, dynamic profession with many specialties, subdisciplines and a variety of practice settings, his own particular area of practice or specialty will be subjected constantly to new information, new concepts, new techniques and new problems. The hundreds of specialty journals that arrive each month at the medical libraries and the increasing size of each year's medical indices are mute testimony to this fact. The important new knowledge that each physician will need to know in the future is unknown now. Some of the facts he has learned as a student in his formal years of medical education will no longer be useful to him in the future because they will be obsolete or incorrect. Neither faculty nor students will ever be able to predict which facts

these will be (West, 1966). Only a portion of what is taught in medical school will be relevant to the particular career in medicine that the student enters as a physician. As a consequence, the physician must continue to learn the rest of his life if he is to be effective, safe, and relevant. Almost all of the learning a physician will need to accomplish in his forty or more years of professional work, after his formal medical education, will be his own responsibility.

The logical second task for the physician, therefore, is to continuously evaluate his own abilities, determine when new skills and knowledge are needed, and effectively use available resources to meet these identified needs. This can be stated as follows: *The physician should be able to continuously define and satisfy his particular educational needs in order to keep his skills and information contemporary with his chosen field and to care properly for the medical problems he encounters.*

If this latter task had been made a priority at medical schools decades ago, the contemporary problems of continuing medical education, recertification, and peer reviews might not be of such magnitude now. Instead, the objective of many medical schools, intended or not, is to ensure that the students become walking encyclopedias of medical knowledge in order to achieve high marks on certifying examinations. We hope that this will shift soon to an emphasis on gaining secure skills in patient evaluation, patient management, and self study.

Vocational versus Scholarly Knowledge

It is unfortunate that many medical school teachers consider the tasks we have just discussed, especially the evaluation and management of the patient's medical problem, to be vocational skills. Their feeling is that these skills would be more appropriately addressed in clinical clerkships, clinical electives, and postgraduate or residency education, and that the responsibility of the undergraduate educational program should be to ensure that the student acquires a firm knowledge base in the basic and clinical sciences. In their opinion, therefore, a physician should be a scholar in the medical sciences and the mission for a medical school is to produce such scholars.

This justifiable concern for a sound knowledge base in the basic sciences and medical specialties has led to a preoccupation with the delivery of content and with measurements of its retention by recall on such objective examinations as the national boards. Scores on these examinations have become the criteria for student and even medical school excellence. As important and essential as this knowledge is, however, its relationship to the purposes of a medical education is distorted. It is important for teachers to realize that the evaluation and management of health problems, whether you

call it medical problem solving or the clinical reasoning process, is the physician's *science* (see Chapter 2 for more detail). This science is definable, amenable to evaluation, and has the potential for being improved upon by appropriate teaching. Basic and clinical science knowledge in medicine must be developed in relationship to the acquisition of this skill.

A student's acquisition of a large body of knowledge in medicine and the basic sciences is no assurance that he knows when or how to apply this knowledge in the care of patients. There is little evidence that the amount of factual knowledge possessed by a student, as scored by objective examinations, correlates in any way with clinical competence (Wingard & Williamson, 1973). A consistently competent clinical performance by a student does ensure, however, that he possesses adequate factual knowledge. This was concisely stated by George Miller, who wrote, "the best performance is built upon sound information; but the provision, or even the acquisition, of sound information is no assurance that it will occur" (Miller, 1967a). In order to solve a problem in mathematics or physics, facts and principles have to be learned. Similarly, great amounts of information have to be acquired in the basic sciences and clinical medicine in order for a physician to evaluate and manage medical problems (Pauker et al., 1976). No scholarship in medical science should be sacrificed through concern for the student's acquisition of clinical problem-solving skills, but it is important that the information is acquired in a manner that permits application to the problems faced by the physician.

Perhaps the appropriate relationship of content knowledge to professional skill or process in medical education might be seen more clearly if an analogy were made to another profession. Commercial aviation is a profession that, like medicine, requires complex skills and public accountability for the pilot's competency. Imagine that you are about to enter a commercial aircraft and that you are told that the pilot has just graduated from a commercial aviation school. To reassure you about this new graduate's competence in the field of aviation, you are told of the important sciences basic to aviation that he has been taught, including physics of flight, geophysics, aircraft design, meteorology, navigation, aircraft engine design and function, hazards in flight, airport design, and so on. To further reassure you of his ability to fly this aircraft you are told that he was given a whole battery of multiple-choice questions and that he had received high marks. He was even given problems on paper, to determine what he would do if an engine failed or a wing was damaged; he handled them very well. It seems doubtful that you would be reassured, despite his scholarship in aviation science, unless you were told that he had proved his proficiency in actual flight maneuvers. Your real concern would relate to his ability to take off, his competency to fly, his ability to get you safely to your destination, and to land. You would hope he

could competently handle any unsuspected, real-life problems or emergencies that might develop during your flight.

If we look in the same manner at medicine, a profession with high public accountability, it seems to us that there should be little argument that

1. The physician should be able to evaluate and manage patients with medical problems effectively, efficiently, and humanely (clinical reasoning).
2. The physician should be able to continually define and satisfy his particular educational needs in order to keep his skills and information contemporary with his chosen field and to care properly for the problems he encounters (self-evaluation and study).

The emphasis in medical education, therefore, must be on the *application* of knowledge.

Selecting Appropriate Teaching-Learning Options

There are many other tasks that the physician must perform in his professional activities, whether they be at the bedside, in the clinic, in the hospital, among his peers, with other health professionals, or in the community. Medical faculties must identify all the tasks they want their graduates to acquire and identify them as objectives of medical education. The relative priority and weight of each task determines the criteria by which the most appropriate teaching-learning techniques can be selected and implemented.

The possible teaching-learning methods in medicine can be conveniently categorized in two ways. The first categorization is based on the person responsible for making the decisions of what the student is to learn. Is it the teacher (teacher-centered) or the student (student-centered)? The second category is based on how the body of knowledge and skills is organized for learning. Does it center on subject areas (subject-based) or problem areas (problem-based)? A curriculum can be teacher-centered/subject-based, student-centered/subject-based, teacher-centered/problem-based or student-centered/problem-based.

Teacher-Centered Learning

In this method, the teacher is solely responsible for what the student is expected to learn. The teacher decides what information and skills the student should learn, how it is to be learned, in what sequence, and at what pace. It is a well-known model that we have been exposed to since kindergarten. Although the teacher's usual role in this method is to dispense information in lectures, assign readings and provide demonstrations, a modular, self-study or

individualized learning curriculum also can be teacher-centered if the teacher determines the modules or resources that are to be studied, the sequence of study, and the learning that is to be mastered. The characteristic that identifies a teacher-centered curriculum is that the student is not responsible for his own education.

Advantages. Experts in specialty or basic science disciplines often find themselves with heavy research and patient-care responsibilities and little time for teaching. In these instances, a teacher-centered curriculum is an ideal format. The expert can readily dispense to the students information and insights gained through his own work in his field through the use of lectures, seminars, monographs, and reading assignments. The teacher can be certain that the student is exposed to all the knowledge and concepts he feels are appropriate for learning. It is easy for a person who has worked many years in a field to synthesize difficult subjects into easily digested capsules, making this a most efficient method for dispensing content knowledge. It saves the student the agony, frustration, and time that would be squandered if he were forced to work through the subject areas on his own.

This is the educational method universally recognized by students, teachers, and administrators. Success as a teacher in this format depends on one's knowledge as an expert and one's flair for dispensing this knowledge. This flair can be expressed in the organization, the insights provided and humor incorporated in the lectures, and in the learning resources used.

Disadvantages. Students are not homogeneous in background, knowledge, or experience, nor are they homogeneous in their learning abilities in different areas or in their pace and style of learning. Each has different career aspirations. In teacher-centered learning, the teacher imposes what he assumes all students should know, without regard to variations in ability, need, or comprehension of new data.

The student is a passive recipient in this method and does not learn to dig it out for himself or "learn to learn." His task is to learn what is offered and to regurgitate it on demand. The students' rewards in teacher-centered learning are usually external, as motivation is invariably based on grades and not on personal desire for accomplishment (Knowles, 1975). Since examinations in this format are centered around the teacher's concept of what is to be learned, the evaluation process is also based on the teacher and not the student. As a consequence, the student does not learn how to evaluate himself against his own concept of what he feels should be learned.

This system makes heavy demands on the teacher, as he must constantly update and revise his material for lectures, readings, or syllabi so that the information he offers to his students is current.

Students and teachers can obtain a false sense of security if they believe that, once information is dispensed and a cognitive framework provided, the student will incorporate the information, recognize where and when it could and should be used, and apply it effectively at that time. Teacher-based learning may be seen as the most efficient method to cover the content to be learned, but it is the most inefficient method to meet the goals in self-evaluation and self-study. In addition, the student is seldom given the opportunity to apply the content learned until after he has graduated, when supervision and assistance are not always readily available.

The final disadvantage in teacher-based learning is that no one can predict which parts of the information the student has learned will eventually become obsolete or incorrect, what the student will forget, or what new information he will need to know in the future (West, 1966). We all can enumerate many important new concepts, skills, techniques, and diseases that have surfaced since we graduated from school.

Student-Centered Learning

In this method, the student learns to determine what he needs to know. Although the teacher may have considerable responsibility in the beginning, by providing the student with the necessary experience and guidance, it is expected that the student will eventually take full responsibility for his own learning. The emphasis is on active acquisition of information and skills by the student, depending on his ability to identify his educational needs, his best manner of learning, his pace of learning, and his ability to evaluate his learning. The teacher is available for guidance as needed until the student gains full independence.

In both the student-centered and the teacher-centered methods, the teacher may prepare what he feels are the appropriate learning objectives, learning resources, and evaluation materials that reflect his particular experience and knowledge. In the teacher-centered approach these materials prescribe exactly what the student is to learn. In the student-centered approach these materials serve as guides and resources to be used and adapted as the student feels appropriate, for taking on the responsibility for his education.

Advantages. In this method, the student does "learn to learn," so that he can meet a lifetime need to adapt to the new knowledge, challenges, and problems he will encounter in the future. He can make his present learning relevant to his educational needs, his future career, and his style and manner of learning, and can pace his learning appropriately, according to his ability to learn or understand in any particular area.

Since his learning is self-determined and acquired through his own "digging" or study, the student becomes an active participant in the learning

process. This provides motivation. More important, what he learns is better retained, because he alone determines what is important to his own study, and seeks out the information himself. His rewards are internal: the desire to learn for personal or professional growth, not for teacher-dispensed rewards.

As the student is responsible for his own education, he also is responsible for the evaluation of his educational goals. The student acquires the ability to evaluate his own strengths and weaknesses, to determine his needs and to learn to meet these needs. The student, with guidance, has to establish his own criteria and methods of evaluation.

The educational work in this format is done by the student. He has the burden of finding up-to-date references or learning resources to meet his needs, using books, monographs, audiovisual resources, and faculty. As a physician, he will have to do this all his life, so it is important that he learn the skill now, during his formal education. The teacher plays a critical, facilitating role, but his main task is to eventually make himself redundant or dispensable to the student's progress. The student learns from the library, laboratory, faculty, and audiovisual resources, thus eliminating the need for endless syllabi, manuals, and reference lists to be prepared by teachers.

Disadvantages. Student-based learning presents a number of organizational problems. Extensive learning resources must be available to the student (books, reprints, slides, videotapes, films, models, specimens, microscopes, cadavers, and so on) so that he can easily pursue his own individual needs. Problems occur because the curriculum must be unstructured in order to allow the student to spend time using the available resources, as he feels appropriate, in order to meet his own educational designs.

Evaluation has to be individualized. The convenience of providing one test for the whole class has to be abandoned. Each student must be evaluated against his own goals. The whole approach to evaluation has to change so that the student is allowed to set his own criteria for success. This is an educational advantage to the student, but the freedom allowed may be seen as a disadvantage to the teacher. There are, of course, certain non-negotiable goals that a medical school must require of its students, if that school is to fulfill its responsibility to the public. The student, by accepting a position in the school, must expect that there will be a number of competencies he will have to possess upon graduation.

This approach can create insecurity on the part of both students and faculty. In the beginning, the student worries about his ability to determine what he needs to know and to what depth. Many faculty cannot imagine how the student can learn on his own and are concerned that he may not learn all that is felt to be important. The student-centered approach requires maturity and discipline on the part of the student and a different order of educational

skills for the teacher, who must be able to facilitate, guide, and evaluate the student as an individual learner, responsible for his own education. These are, however, qualities that the student, in his eventual role as a physician, must possess. What better time to develop them than medical school, where their effective growth can be monitored and enhanced by teachers?

Subject-Based Learning

In this most familiar method, the learning is organized around a subject area or field of learning in medicine or the basic sciences, such as anatomy, pharmacology, biochemistry, laboratory medicine, surgery, pediatrics, or neurology. Learning may be organized into a hierarchy of basic concepts that build up to more advanced concepts. The objective is for the student to gain an overall grasp of the subject area involved, to learn its important concepts in sufficient depth, to have an understanding of the field itself, or to apply concepts from that field to his future task as a physician. Again, this method is independent of the format, since subject-based learning can be individualized and self-paced. It does lend itself well to larger classroom approaches. It can be either student- or teacher-centered, as long as learning is organized around a subject.

Advantages. In this system, the end points or limits to student learning are defined by the subject area, as is the sequence of learning. The extent and depth of knowledge to be acquired is more easily defined for the students and the teacher.

Resources for learning in one specified subject or field are more easily identified and made available for student use. Teachers have more confidence in specifying all concepts and skills they feel need to be learned by the students.

This approach seems efficient, since the student applies himself to the task of memorizing and/or manipulating the concepts, skills, and information that are important, quickly and directly. Evaluation is easily designed to sample the student's recall of the specified knowledge and concepts identified, through the use of convenient and well-established tests (multiple-choice, true-false, word fill-in, and essay examinations). The student's successful recall of information provides both the teacher and the student with a feeling of security that adequate learning has occurred. This can be a disadvantage in that the student may feel immunized against any need for further learning in the subject area.

Disadvantages. The information learned in this approach can be reinforced only by experiences that require recall of the information learned. In subject-based learning this information is not readily recalled or reinforced by work

with patients, since it is learned in association with an organized subject. Generations of students in conventional curricula have expressed the desire to repeat basic science courses when they enter their clinical years, testimony to their frustration over the inability to recall subject-based information from earlier years.

In subject-based learning, the information acquired is not conveniently integrated with information from other disciplines or subject areas. Even in so-called "integrated curricula," the student is exposed to juxtaposed information with no central focus around which to organize in his memory, except for the subject or course.

Although this method enhances the memorization and understanding of a large body of information in one subject area, it does not ensure that the student will be able to select in a problem situation the item of information from the specific discipline that will be helpful to him. The types of problems he will encounter as a physician will require the integration of many bits of information and skills from a variety of disciplines. If the cognitive connections among subjects are not actively laid down during the learning process, one cannot expect the student to intuitively develop these connections when faced with a patient problem where information from a variety of disciplines has potential application. How can subject-based learning be considered efficient in the long run if patients do not present themselves as isolated examples of information from one discipline?

This method of learning tends to reward the good memorizer and often inhibits the student who likes to learn by reasoning or inquiry. This latter skill often is not stressed in subject-based learning, yet it is a necessary cognitive behavior for the practicing physician.

Problem-Based Learning

In this approach, the student takes on a patient problem, a health delivery problem, or a research problem as a stimulus for learning in the areas, subjects, or disciplines that are appropriate for the student at the time. In doing this, the student exercises or further develops his problem-solving skills. This method of learning has two educational objectives: the acquisition of an integrated body of knowledge related to the problem, and the development or application of problem-solving skills.

Problem-based learning is ideally suited for student-centered and individualized learning. It can be used, however, in teacher-centered learning. The teacher can specify the problem to be used, the areas of study, and the resources or subjects to be studied relevant to the problem. This will develop students' problem-solving skills and involve them in the active acquisition of knowledge, but they are not challenged to learn for themselves. The term problem-based learning, as used here, implies student-centered learning as well.

Advantages. This approach is tailor-made for medicine. It provides advantages for both the acquisition of knowledge and the development of essential skills in patient problem solving. Information, concepts, and skills learned by the student are put into his memory in association with a problem. This allows the information to be recalled more easily when he faces another problem in which the information is relevant. Recall is constantly reinforced and elaborated by subsequent work with other problems. The student is able to use the problem as a focus for the study of many different subjects, actively integrating this information into a system that can be applied to the problem at hand and to subsequent problems.

By working with an unknown problem, the student is forced to develop problem-solving, diagnostic, or clinical reasoning skills. He must get information, look for cues, analyze and synthesize the data available, develop hypotheses, and apply strong deductive reasoning to the problem at hand. This approach is very motivating to students; medical students especially like to work with and solve patient problems, since this challenges them with the very situations they will face in their elected professional field.

Many studies have suggested that the effectiveness of the physician's diagnostic or clinical reasoning skills correlates directly with the experience and learning gained from prior patient problems. This is another endorsement for problem-based learning, since learning with this format requires the students' active participation in a large number of health problems.

When his learning is centered around patient problems, the student can see the relevance of what he has to learn, particularly the importance of basic science information to his future tasks. Problem-based learning will teach a skill that will continue to be useful to the student's professional life, where patients become the stimulus for further learning.

An added reward to problem-based/student-centered learning is the inevitable discovery, by teachers who become comfortable with this approach, that this method is enjoyable, rewarding, more natural, and actually takes less time. In student-centered work, the student carries out much of what was teacher activity. This approach is further enhanced by the responses seen in students. They become excited, motivated, evidence more mature behavior (they are being treated as self-determining adults), evolve secure clinical reasoning and learning skills, and acquire an impressive groundwork of basic knowledge.

Disadvantages. The success of problem-based/student-centered learning depends on students disciplining themselves to work with an unknown and possibly puzzling problem in a way that will challenge the development of their problem-solving skills and stimulate relevant self-directed learning. The teacher must have the skills necessary to orient and guide students in this

process and to design as well as produce or assemble problem-based learning materials (see Chapter 9).

There are several concerns that often weaken the perceived value of problem-based learning. The first is the feeling that this method stresses the clinical concepts of patient evaluation and management, to the detriment of learning in the basic sciences. The second is that this method seems to stress problem-solving skills and not the acquisition of knowledge or facts. Both are unfounded if problem-based learning is correctly implemented. Experience has shown that students, if properly oriented and guided by medical teachers, can learn basic or clinical science in any area and to any depth. The challenge in working with a patient problem does not have to be the diagnosis or differential diagnosis of the problem. It just as easily can be to identify the underlying anatomical, biochemical, or physiological mechanisms involved in the problem and to understand how they function. The most important factor in the student's effective use of the problem is a clear understanding of the educational objectives of the program or unit. This provides both students and teachers with guidelines as to what possible areas they should pursue in working with the problems they have decided to use.

A third concern is that problem-based learning seems to be an inefficient way to learn. When confronted with an unfamiliar problem, the student requires considerable time to understand the terminology; the significance of symptoms or signs; the basic anatomy and physiology of the organ systems involved; and the social, epidemiological, or psychological dynamics in the problem. There are so many important and relevant areas that could be studied in any problem, it may seem as though an inordinate amount of time must be spent to complete the first problem in a new area. In actual fact, there is little inefficiency, since much of this study provides the factual groundwork for understanding other problems. As the student begins to grasp the basics, he moves more swiftly with subsequent problems on the knowledge he has gained from the first, while constantly reinforcing what has been learned.

This method of learning does not facilitate the student's ability to pass certifying examinations (national boards, multiple-choice, true-false) that largely stress recall of isolated facts and concepts. Recall occurs best for the student in this system when he is faced with a problem, not when he is faced with subject-oriented questions. Problem-based learning requires different types of examination tools that evaluate the student's ability to work with problems and apply learned information to their understanding or resolution (see Chapter 7). Many of the techniques and measurement tools used are unfamiliar and may seem "soft" to many teachers.

For both the teacher and the student, this approach requires considerable attention to learning objectives, identification of appropriate educational

issues, and knowledge of the physician's cognitive processes and how they should be learned and evaluated.

Summary

It could be assumed easily that teacher-based learning refers to lectures and that student-based learning refers to individualized or self-directed study. There is no doubt that teacher-based learning is easiest with the lecture format and student-based learning can be facilitated best by self-study units of one type or another. It is important, however, to see these approaches as independent of format. The lecture can be student-based if students ask you to give a lecture on a subject they have decided is important for their learning at a particular point. Self-study units can be teacher-based if the teacher determines the units to be studied by the students, specifies the reading and other experiences that should be undertaken, the time to be taken, and gives an examination at the end to see if the students have learned what was felt by the teacher to be important.

The Appropriate Teaching/Learning Combination for Medicine

Certainly the most common combination of teaching and learning that occurs in medical schools is teacher-centered and subject-based. Knowles (1975) points out that teacher-centered, subject-based learning assumes that the learner's experience in learning is of less value than the teacher's. He also points out that the real competencies needed by students in teacher-centered, subject-based learning are to listen attentively, take careful notes, read rapidly with comprehension, predict examination questions, and be able to cram. He states that all that is required of the student in this method "is that he learns the material presented to him, and that he is able to reproduce it as accurately as possible on demand. As long as the product, i.e. precise reproduction, is correct, we are satisfied." West (1966) adds, "In general the atmosphere of a great many if not most, American medical schools appears to be one in which the faculty assumes responsibility for presenting a common body of subject matter to all students and the students assume the responsibility for repeating it on demand."

If the educational program is built around lectures, it is important to recognize that they cannot be delivered at the convenience of the learner, nor can they be given at a level, pace, and priority important for the individual learner in the class. Lectures are often unrelated to any active application by the student and, by the time he needs the information given, it is forgotten. In fact, George Miller (1962) points out that, before they graduate, medical

students forget most of what they learn in traditionally taught first-year anatomy and biochemistry. Knowledge *used* is better remembered.

When problem-based/student-centered learning is considered, however, the teacher's concern is that the method seems inefficient. This displays a blindness to a crucial issue: It is more important to consider how much the student learns than how much the teacher teaches. Typically, teacher-centered learning is concerned with transmission of content by the teacher. Student-centered learning is concerned with the acquisition of content by the student. In problem-based/student-centered learning, not only is knowledge acquired but skills in *using* knowledge are acquired (Knowles, 1975).

Perhaps one of the most important advantages of student-centered learning is that the student is motivated by the internal rewards of learning and not by the artificial or external rewards of grades. This produces a different climate in a medical school. The students are "turned on" constantly, they assist each other, and an informal collaborative relationship with faculty ensues. In addition, their learning is motivated by personal satisfaction, which will always be present, even when grades and passing exams are no longer an issue.

If we expect a student to develop (1) the ability to evaluate and manage patients with medical problems effectively, efficiently, and humanely (clinical reasoning skills) and (2) the ability to define and satisfy his particular educational needs to keep his skills contemporary with his chosen field and to care properly for the problems he encounters (self-directed study skills), it seems obvious that problem-based/student-centered education should be the principal method employed in medical school. Alternative techniques simply cannot compete with this method when it is realized that problem-based learning is the one that will help the student develop medical problem-solving skills. Additionally, it is the only method that ensures that the content learned is related to the task of resolving problems, reinforced in the student's memory by reuse with multiple patient problems, and made useful to the problem solver by the active and ongoing integration of information from many disciplines. The generalization of the principles learned with each problem ensures transfer of information and skills to the student's work with subsequent problems. Only student-centered learning will help the student to "learn to learn," a lifetime need for his professional work.

Faculty Members as Problem-Based Learners

Although there is a growing body of literature documenting the value of problem-based learning in education, we as teachers only need to reflect here on how we continue to learn and acquire information. All of us

attempt to stay abreast of the literature in our particular area of specialty or expertise. We voraciously read our monthly journals and attend conferences and seminars, yet, most of the material covered in these endeavors is soon forgotten. If we run into a complex or difficult patient case or research problem, however, and have to read, talk to experts for advice, or research the literature for help, the information we gain invariably is far better retained. When you face another problem that is similar, it all floods back into your awareness, sometimes it seems as if by magic. In the study of the physician's problem-solving skills that will be described in the next chapter, it was not an infrequent occurrence for a physician suddenly to recall from his memory a sophisticated package of information to help evaluate or manage the patient problem he encountered. If you ask how he did it, he invariably will recall a case, a patient, or a similar problem he worked with months or years ago. Whenever a bright idea suddenly occurs to you in your work, reflect; it probably came from a previous problem. The journal, convention, and seminar approaches are teacher-centered and often subject-based. The puzzling over a problem in work is obviously problem-based/student-centered, self-directed learning. If it works so well for us, why not share it with our students?

However, experienced professionals probably learn more useful information from subject-based approaches, such as lectures and journals, than do students. They have a backlog of patient experiences and problems that can make the information relevant and its application in future use easily perceived.

Problem-Based Learning for Team Learning

Problem-based learning provides a potent format for interprofessional learning in the health sciences. Since the patient and his problem are the focus for health-care delivery, around which all members of the team perform, a problem can serve as an organizing structure for students from various professions to develop an understanding of each others' concerns and skills and to develop a team approach. They can discuss the concept each has of the patient's problem and how these fit together. They each can use the problem as motivation for study of the relevant areas from their own professional discipline and then decide on management and the appropriate use of their individual or complementary roles. We have had very productive experiences with problem-based learning for medical-student/nursing-student learning and for nurse/physiotherapist/physician team learning.

This emphasis on the advantage of problem-based learning does not mean that it is the only method appropriate in medical education, but that it should be a principal or major method. There are many occasions where other

methods may meet certain educational objectives better; however, the usual employment of teacher-centered/subject-based learning as the principal or major method is not appropriate.

The Challenge of Applying Problem-Based Learning

With the rationale for problem-based learning in medical education now fully discussed, the focus of this book becomes the practical application of this technique. Teacher-centered/subject-based approaches are completely familiar to all of us, and we would have little difficulty in designing, selecting, or carrying out the educational activities needed in this approach, such as objectives, teaching methods, learning resources, and evaluation methods. Problem-based learning and self-directed learning, however, offer a new set of challenges in selecting, designing, and carrying out these functions. Facilitatory teaching skills are required. Problem-based learning units that are separate from learning resources are needed. Simulations of patient problems are needed to maximize the problem-based learning experience. Different evaluation tools to analyze the student's process of problem solving or clinical reasoning are required. A restructuring of time and teacher use may be needed. The task of this book will be to provide a more detailed discussion of these areas. In doing this, we hope to show how education can be an applied science where one uses the same logic as applied to research and patient care.

In summary, problem-based learning can be defined best as the learning that results from the process of working toward the understanding or resolution of a problem. The problem is encountered first in the learning process and serves as a focus or stimulus for the application of problem-solving or reasoning skills, as well as for the search for or study of information or knowledge needed to understand the mechanisms responsible for the problem and how it might be resolved. The problem is not offered as an example of the relevance of prior learning or as an exercise for applying information already learned in a subject-based approach. A problem in this context refers to an unsettled, puzzling, unsolved issue that needs to be resolved. It is a situation that is unacceptable and needs to be corrected. Finding the answer to a question is not problem-based learning. The use of a known principle or solution to explain an observation or phenomenon is not problem-based learning. The most frequently used problems are patient problems, which need not be classical diagnostic entities or even resolved problems in order to be useful. Problems other than patient problems also can be used to stimulate student reasoning and learning. Evaluation of research results or journal articles, health-care-delivery problems, medical research problems, hospital or practice administrative problems, team function problems, and so forth, all can be used to achieve appropriate objectives in medical education.

CHAPTER 2

The Clinical Reasoning Process: Problem Solving in Medicine

Background

The most important set of abilities the physician must possess are those involved in the clinical reasoning process. This term refers to the cognitive process that is necessary to evaluate and manage a patient's medical problems. This process is quite similar, if not identical, to the hypothetico-deductive reasoning process attributed to scientists working within their particular disciplines. The clinical reasoning process should be considered the "scientific method" of clinical medicine. Although many terms have been used to describe this cognitive process, such as medical problem solving, medical inquiry, clinical judgment, and diagnostic reasoning, *problem solving* is the most commonly used.

It is unfortunate that, in medicine, the term implies that the task of the physician is primarily one of solving problems. Since many medical problems are insoluble, the usual task of the physician is to evaluate or analyze his patient's problems as far as possible or necessary, so that they can be managed effectively. Problem solving also suggests that the intellectual process of finding the solution, as in a puzzle or in a mystery, is the objective or end point to this skill, when the treatment or therapeutic aspects of the process really are the appropriate end point. A great deal of undergraduate teaching incorrectly puts emphasis on diagnosis and differential diagnosis as the appropriate end point in working with patient problems. The term problem solving reinforces this emphasis. The term *medical inquiry* focuses on the data-gathering or evaluative aspect of this process, and the terms *clinical judgment* or *medical decision making* focus on the decision-making component of this