The Cultivation of Medical Expertise in Small Group Process

by

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Abstract

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Introduction: Small Group Process (SGP) is a form of problem-based learning that stimulates students to explore basic science domains through the use of clinical cases. Emphasis in SGP is on the explanation of the relationships between basic science and clinical medicine in a cooperative setting. While theories exist expounding the benefits of problem-based learning, there is a paucity of research documenting what exactly underlies the transformation of the medical student into an expert clinician. Thus, the pathway to expertise -- the goal of medical education -- remains undefined. The purposes of this study are: (1) to characterize the cognitive activities that students practice in SGP; and (2) to relate these activities to theories of medical learning and models medical expertise.

Methods: Quantitative and qualitative data were collected from students and instructors during a semester-long Neurobiology course in the form of cognitively-based evaluations and learning style questionnaires. Several class sessions were transcribed and coded for interaction, subject content, and cognitive activities.

Results: Students spend one-third to one-half of SGP sessions actively discussing basic science concepts both in and out of the context of clinical problems. Approximately one-

seventh of the time is spent organizing learning goals, group directions, and out-of-class study.

Conclusions: SGP encourages an explanation-based learning of the basic sciences. In working together, students practice many cognitive skills that have been identified as essential characteristics of expert clinical care. However, the actual cognitive processes of the expert differ significantly from those of the novice. Thus, the author argues that SGP, like any other teaching method, does not and cannot explicitly teach the reasoning processes of expert medical cognition.

To all of my students who listened and Jess who questioned

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Chapter One: Literature Review

I. Introduction

> The medical course cannot produce a physician. It can only provide the opportunities for a student to secure an elementary knowledge of the medical sciences and their application to health problems, a training in the methods and spirit of scientific inquiry, and the inspiration and point of view which come from association with those who are devoting themselves to education, research, and practice. Medicine must be learned by the student, for only a fraction of it can be taught by faculty. The latter makes the essential contributions of guidance, inspiration, and leadership in learning. (p. xiv)
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> -- *W.C. Rappleye, AAMC Commission on Medical Education, 1932*

Medical schools have a daunting task: to provide a person with the biological, psychological, and sociological knowledge to care for someone else's life and well-being. This foundation of clinical knowledge must be formed in only four years. Medical schools carry the responsibility for guiding students toward the knowledge, skills, and attitudes that will make them effective health care providers. In turn, students must continue to educate themselves throughout their medical careers to sustain a certain level of competency. Since the call for standardization of medical education by the Flexner Report at the turn of the century (Flexner, 1910), US medical schools have been grappling with ever-growing lists of requirements for their students. Over the last twenty years, Problem-Based Learning (PBL) methods[1] have replaced lectures in some medical classrooms with the hope of encouraging student-driven inquiry and self-directed learning. The expectation of such

[1] I am including various cooperative teaching methods (i.e. those requiring students to work together to learn) under PBL. Discussion in cooperative teaching methods in medicine will often be driven by a problem, even if the discussion is focused on understanding the information of a domain (i.e. a discipline's body of knowledge) and not wholly the problem itself.

inquiry is that students will acquire the cognitive skills that enable a life of continuous learning in medicine (Norman & Schmidt, 1992).

Many curricula use variations of PBL in the medical and health-related fields. One can find examples in nursing (Hiebert, 1996; Goodfellow, 1995; Beck, 1995; Stockhausen, 1994; Moses, 1992; Glendon & Ulrich, 1992), physical therapy (DeClute & Ladyshewsky, 1993), osteopathic medicine (Johnson et al., 1992), clinical (Chapman et al., 1996; Timpka & Marmolin, 1995; Mold et al., 1995; Levitt et al, 1994; Marvel et al., 1993), and undergraduate medical education. Within undergraduate medical education, PBL has been used to teach entire curricula (see Albanese & Mitchell, 1993 for a meta-analysis) as well as subsets of other curricula such as communication skills (McManus et al., 1993; Lynch et al., 1992) and introductory clinical reasoning (Slavin, et al., 1995; Rogers et al., 1995; Lewkonia et al. 1993; Thomas, 1992).

Because PBL environments are more complex than traditional lecture-based classrooms, their success is extremely variable. Unlike lectures, successful PBL classrooms depend on more than just the instructor's ability to communicate knowledge clearly. Their success also depends on student interactions and the tutor's subject matter knowledge, facilitation skills, and communication skills (Schmidt & Moust, 1995; Schmidt, 1994, Schmidt et al., 1993). The classroom interaction brings numerous skills and attitudes into the learning process. The quality of the PBL learning process depends on both the instructor and the participating students working together in a succession of somewhat unpredictable interactions. In recent years there has been a growing body of research focusing on differences between PBL and conventional medical curricula (Albanese and Mitchell, 1993). However, there remains little known about the learning processes encouraged by PBL classrooms.

The purpose of this paper is to characterize a particular type of PBL called Small Group Process (SGP) and understand its cognitive value in undergraduate medical divided into two categories: inert and active (Brien & Eastmond, 1994). Inert knowledge, a phrase coined by Alfred North Whitehead in the early 1900s, refers to knowledge that is committed to memory but not applied to a task or a situation. For example, a student may learn the cardiac cycle from a textbook. This knowledge is untested and as such is information that the learner does not know how to apply correctly in the real world. Active knowledge, on the other hand, is knowledge that the learner has applied. If our student were to use her knowledge of the cardiac cycle to care for a patient in congestive heart failure, she would not only know what the cardiac cycle is, but also how to apply it to a situation. She thus transforms the cardiac cycle concept from a simple set of facts (inert knowledge) into a functional concept (active knowledge). Alfred North Whitehead (1929) states, "utilizing an idea... [relates] it to that stream, compounded of sense perceptions, feelings, hopes, desires, and of mental activities adjusting thought to thought, which forms our life.... Education is the acquisition of the art of the utilization of knowledge." Applying knowledge makes one consider the value, the universality, and the relation of a piece of information in the context of the other pieces of information that real world tasks require.

An *attitude* is defined as "a feeling or emotion toward a fact or state". Attitude comprises a broad range of psychosocial issues. One focus of this paper is how a student's attitude about their learning style impacts upon the perceived effectiveness of a teaching method. Kolb's experiential learning theory (Kolb, 1981) divided learning into four major activities: (1) concrete experience; (2) reflective observation; (3) abstract conceptualization; and (4) active experimentation. As an individual matures, s/he tends to move towards one pole of two axes, gaining a self-concept of how s/he learns the best. One axis aligns the concrete-abstract poles, the other axis aligns the reflective-active poles. In theorizing about disciplinary differences in learning styles, Kolb (1984) hypothesized that the majority of learners in medicine would be amalgams of all four types of learning poles, thereby possessing a broad palette of styles that would permit adaptability to multiple tasks. Drawing from this model one would expect medical students to succeed relatively equally across different classrooms because of their ability to adapt to a variety of educational requirements.

A *skill* is a broad term that may be divided into two major groups of skills: procedural skills and cognitive skills. Procedural skills are physical. Handling an otoscope, performing a biopsy, and writing while rushing down a hospital corridor are all procedural skills. They require a physical ability to carry out a task. Cognitive skills are mental. In defining cognitive skill acquisition, VanLehn (1996) defines a cognitive skill as "the ability to solve problems in intellectual tasks, where success is determined more by subjects' knowledge than by their physical prowess." This broad definition clearly separates cognitive skills from procedural skills. However, it does not give much insight into what *specific* cognitive skills comprise expert thinking. Indeed, there is a paucity of research on cognitive skill acquisition in the transition from novice to expert in any domain (VanLehn, 1996).

The overall goal of medical education is to set the novice on a pathway that leads towards expertise. Together, knowledge, skills and attitudes define that pathway. Having defined these terms, the discussion will now explore how cognitive skills may be incorporated into medical education.

III. Learning objectives

> If we indoctrinate the young person in an elaborate set of fixed beliefs, we are ensuring his early obsolescence. The alternative is to develop skills, attitudes, habits of mind, and the kinds of knowledge and understanding that will be the instruments of continuous change and growth on the part of the young person. Then we will have fashioned a system that provides for its own continuous renewal.
>
> -- John Gardner, *Self-Renewal: The Individual and the Innovative Society,* 1964.

Following the thoughts of Dewey, Gardner envisions education as providing the individual with a set of skills that permit life-long change and self-renewal. The objectives of undergraduate medical education are primarily set in the context of basic science knowledge. Learning tends to proceed along such objectives, thereby permitting students to neglect pursuing the skills required to interpret and update that fund of knowledge. After a brief discussion of informational objectives, the paper will focus on characterizing the cognitive skills that might allow for the "continuous renewal" of one's understanding and medical expertise itself.

A. Informational learning objectives

As stated above, much of medical teaching and learning is based on the informational criteria set and tested by the Federation of State Medical Board Examiners (FSMBE) and the National Board of Medical Examiners (NBME) (Swanson et al., 1992; AAMC, 1984). A topic list is published yearly to inform students and faculty of the testable subject areas that may be considered by the NBME on the United States Medical Licensing Exam step I (USMLE I). The purpose of this exam is to assess whether an "examinee understands and can apply key concepts of basic biomedical science with an emphasis on the principles and mechanisms of health, disease, and modes of therapy." (FSMBE, NBME, 1996)

The traditional, lecture-based medical curriculum assumes that in committing biomedical science concepts to memory, one will create an integrated knowledge base sufficient to support clinical thinking. How does the medical student progress from memorized fact to clinical thinking? As noted previously, knowledge committed to memory is inert until employed in a context. Thus, setting learning objectives that are purely informational in scope falls short of the NBME's intention. While a student might understand a concept, this does not mean that s/he can apply it correctly. Thus, it seems the goal of UME should comprise more than understanding. It should stimulate and assess the practice of applying knowledge as well. Furthermore, the practice of medicine also requires an ability to communicate one's understanding to others in clinical problem-solving with patients and fellow health-care workers. Two question arise: what skills are required to apply knowledge to problems? What other skills are required of a medical expert in order to practice skilled and compassionate medicine? The next section explores the skills that are set nationally as objectives for graduating physicians.

B. Skill learning objectives

While there is a plethora of information-oriented learning objectives for pre-clinical training (NBME, 1997), there is no corresponding set of skill-oriented objectives. This is in contrast to clinical medicine in which specialty and subspecialty boards determine and publish sets of skills relevant to clinical practice. The search for skills essential to the practice of medicine has yielded multiple lists. The AAMC (1984) identifies several "qualities" that should characterize all physicians:

• to be caring, compassionate, and dedicated to patients

• to be committed to work, to learning, to rationality, to science, and to serving the greater society

• to be able to weigh the possibilities and to devise a plan of action responsive to the personal needs of each patient

• to strive to attain and maintain the above attributes

All of these represent skills. One might argue that compassion is not a mutable skill as is, for instance, devising a plan of action to solve a clinical problem. However while one's personality may be relatively fixed by the time one reaches professional school, one's procedural ability to express concern, to listen, and to accommodate others most likely is not. While it seems ridiculous to change a student's sociopolitical attitudes, improving the student's ability to show restraint, compassion, or interest to patients does not. The following quote identifies multiple skills essential to the clinician, linking the ability to establish rapport with patients to the actual diagnosis and treatment of their disease:

> ... skills in the collection of information from and about patients, in the establishment of rapport with a patient to facilitate both diagnosis and therapy, in the application of the scientific method to the analysis, synthesis, and management of problems, in the identification and critical appraisal of relevant literature and clinical evidence, and in the continuation of effective learning. (p.1)

These skills were echoed in 1991 when the Pew Health Professions Commission surveyed medical doctors, asking them to rate the importance of acquiring various skills during their medical school training. Among the statements rated most important were: diagnosing and treating disease (97%), communicating effectively with patients and families (92%), problem-solving and independent thinking (88%), and pursuing a lifetime of continuous learning (83%) (Finnochio et al., 1995). This albeit short list of cognitive skills begins to form a picture of the perceived skills that contribute to the target of medical education -- medical expertise. However, defining objectives does not necessarily guarantee their reflection in teaching or learning. Certainly, lecture-based curricula would be limited in their ability to cultivate these skills.

While these skills are recognized as important for one's medical education, they are rarely referred to explicitly in the pre-clinical courses of UME. Instead, they are left unstated or largely undefined. Bloom (1989) states:

> Medical education, much like medicine itself, tends to be perceived primarily as an intellectual activity.

> Notwithstanding the ever-present reminders that medicine is a consulting profession and not a unified scholarly discipline, the emphasis in training for the profession is on medical knowledge and its development. Accordingly, the focus of inquiry about medical schools has been on ...how teachers transmit ideas and how students acquire them. Thus, goals of performance, of professional behavior, are subordinated to goals of ideation. The assumption is that behavior follows from knowledge. (p. 232)

If the goals of communicating effectively and pursuing self-directed study are not explicitly stated, as are the basic science objectives in UME, then how is the medical student or faculty to know that these are valuable and intended educational objectives? Unstated learning objectives are rarely learned (Resnick & Resnick, 1992). It seems unlikely that learners faced with volumes of medical information to "master" would also voluntarily undertake defining and acquiring the specific cognitive skills that characterize the expert clinician. While informational objectives abound, the difficulty in lecture-based learning is the dearth of identified skills and attitudes with which to contextualize learning. How can such objectives be incorporated into the medical curriculum?

Problem-Based Learning (PBL) attempts to incorporate the goals of performance that Bloom refers to above by requiring learners to actively pursue knowledge rather than be passive recipients of it (Norman & Schmidt, 1992). The key assumption is that this pursuit of knowledge stimulates the acquisition of skills that experts use in their own problem-solving process. The student acquires the knowledge and the skills relevant to thinking in that domain in parallel (Barrows, 1988). Whether or not the knowledge gained through problem-solving is qualitatively different from that gained passively is controversial (Norman & Schmidt, 1992). PBL is only an approximation of the actual practice of medicine and medical thinking. While the cognitive skills that it stimulates the student to practice may overlap with the skills of an expert clinician, they might not be entirely identical. Indeed, the objectives of these two activities differ. While clinical thinking is directed at solving a clinical problem, PBL is directed at *using* a clinical problem to stimulate the learning of related basic science concepts. This difference in intention may give rise to differences in cognitive practice.

C. How might a teaching method implicitly address skill acquisition in a learner?

The AAMC's goal of stimulating "active learning" in medical education requires additional structuring of the educational environment. While passive learning is guided by the expert in his or her lectures, active learning can be thought of as goal-driven learning that requires the identification and pursuit of specific knowledge goals by the learner (Ram et al., 1995). Goal-driven learning requires multiple skills. Ram et al. (1995) describe characteristics of their model of goal-driven learning as being: (1) *active* ; (2)*experiential*, occurring through performance of a reasoning task; (3) *opportunistic* in that goals not immediately satisfiable are postponed to times when opportunities arise to meet them; (4) *diverse*, requiring multiple strategies to acquire, construct, and re-organize knowledge; and (5)*introspective*, requiring reflection on one's performance (e.g. learning from one's mistakes) as well as monitoring one's progress towards established learning goals (Ram et al., 1995). Each of these characteristics connotes a different set of cognitive skills that a learner must exercise in pursuing active, goal-driven inquiry.

Expecting a learner to cover the same breadth of knowledge in a domain through active inquiry to the same extent that s/he might cover it in a passive learning environment is unreasonable. In addition to the informational goals of the inquiry process, the learner must also identify and practice the cognitive skills that support active exploration of the domain. One may think of a course's educational objectives as being the product of the number of skills the student is to acquire and the quantity of factual knowledge the student is expected to achieve. This product is a constant reflecting the limited time and cognitive resources of the learner:

(Skills student practices)(Factual knowledge) = *K (cognitive performance)*

A learning environment that stimulates active pursuit of knowledge thus limits the breadth of content coverage in a domain. As more skills are added to the learner's list of objectives for the classroom (i.e. what s/he is supposed to practice and learn via the teaching method), content coverage must decrease. This is not to say that learning is compromised. Rather, the student's cognitive engagement is distributed amongst cognitive skill acquisition and knowledge acquisition.

1. Objectives of the teacher (intentions of teaching method)

Cooperative learning is a teaching method that is associated with the development of higher order thinking skills and prosocial behavior (Cohen, 1994). The educational outcomes of such a classroom are unique to the structure of the learning environment. Noddings (1989) refers to such outcomes broadly as the "productivity" of the classroom. Interactions that occur in cooperative learning stimulate the development of cognitive skills and conceptual learning. In this sense, the intended objectives of the classroom's structure are not derived simply from the content of the domain, but rather include certain specific cognitive skills that are implicit in the structure of the teaching method.

Barrows (1988) describes many cognitive skills that are required of the learner by cooperative PBL classrooms. In addition to the information that students in the traditional lecture-based track must learn, students in the PBL track must also acquire and exercise skills such as deciding the quality and relevance of multiple information resources, making decisions about a problem based on intuition or probability, critiquing the adequacy of one's knowledge, and using such knowledge to direct one's further learning. Indeed, it appears that PBL's intentions overlap significantly with Ram et al.'s (1995) concept of goal-driven inquiry.

2. Objectives of the learner (expectations of and reactions to method)

In a given teaching method, not all learners may achieve skills and knowledge to the same extent. Learners may have different learning goals for themselves. Research suggests that students learn at different rates, possibly because they use different studying strategies and different kinds of reasoning during learning (VanLehn, 1996). Bruner (1985) theorizes that people adapt their approaches to learning based on the domain in which they find themselves. In this sense, learning strategy is context-sensitive and, if one is to learn in a domain, one must adopt learning strategies that best suit the task at hand. Bruner goes on to advise instructors to embrace the diversity of learning strategies in instruction:

> ... the best approach to models of the learner is a reflective one that permits you to "go meta" [use metacognitive skills[2] to adjust learning], to inquire whether the script [teaching method or feature thereof] being imposed on the learner is there for the reason that was intended or for some other reason. ... We would do well to equip learners with a menu of possibilities and, in the course of their education, to arm them with procedures and sensibilities, that would make it possible for them to use the menu wisely. (p. 8)

Bruner's emphasis on reflectivity parallels the introspectiveness of Ram's model of goal-driven inquiry. In actively pursuing knowledge, the student must also pursue self-awareness of his or her learning process in an effort to fit the learning strategy to the task. This leaves open the possibility for the student to exercise skills or strategies of learning that may not be the expected strategies of the instructor. Indeed, the intended goals of the

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[2] metacognitive skills are skills that allow one to reflect, understand and analyze how one learns.

instructor and the learning intentions of the student are often not the same (Ng & Bereiter, 1995; Dolmans et al., 1993; Resnick & Resnick, 1992; Swanson et al., 1992). In three separate studies of medical courses, the average percentage of faculty learning objectives that medical students considered relevant to their learning ranged from 42% to 68% (Dolmans et al., 1993; Tans et al., 1986; Coulson and Osborne, 1984). Perhaps making the instructor's intended learning strategies and the strategies employed by the learner explicit would bridge the gap between these learning objectives. One should not assume that a learner will employ a particular learning strategy in a given situation. If the structure of a course is meant to elicit certain behaviors or practices, these outcomes should be present from the beginning rather than discovered at the end of the course.

The theory of cognitive styles contrasts Bruner's idea of cognitive strategies. While the learner can employ or alter cognitive strategies, his or her cognitive style is not so mutable (Kolb, 1981). Cognitive style refers to a learner's tendency to learn in a specific way. For example, one may learn best by talking through problems with others rather than sitting alone and contemplating theories. Multiple cognitive strategies adapt one's cognitive style to the learning task. Congruence between a teacher's and a learner's cognitive styles may lead to greater mutual acceptance in learning and, therefore, greater congruity between student and instructor goals for learning (Bertini, 1986). Students who possess learning characteristics "congruent" with those of the instructor may perceive greater skill acquisition because of their overlapping sets of cognitive expectations from the classroom process. Students with non-congruent characteristics potentially have two strikes against them: (1) s/he comes to the classroom with a self-concept of learning that is contrary to some of the expectations of the instructor; and (2) s/he employs learning strategies that are not cognitively congruent with the intentions of instruction.

Of importance, however, is the qualification that congruence between student and instructor may not necessarily lead to improved learning. Witkin (1977) hypothesized that excessive congruence in the classroom, whether between students or between student(s) and instructor(s), decreases the diversity of learning practices. Restricted exposure that students have to other cognitive styles prevents one's own learning methods from being challenged and thereby modified over time. According to Bruner's concept, then, as the student "goes meta", s/he will have a larger set of strategies to choose from. This is also consistent with Ram et al.'s expectation that goal-driven inquiry be diverse in strategies and introspective to permit selection of those strategies.

D. Explicitly defining skill sets for learners

When learning cooperatively, students automatically adopt a variety of explicit "thinking roles" such as: (1) executive -- designing and planning group action; (2) critic -- questioning the ideas of the group; (3) instructor -- explaining and summarizing that which is discussed; (4) record keeper -- keeping track of the group's learning; and (5) conciliator -- resolving conflict within the group (Bales, 1950; Dashiell, 1935; Kelley & Thibaut, 1954; Shaw, 1932). In creating a teaching method known as reciprocal teaching, Brown and Palinscar (1989) studied the effect of overtly stating or defining specific cognitive roles to learners. In cooperatively constructing meaning, students took on the roles of questioning, clarifying, summarizing, and predicting. When compared to explicit instruction, these students showed significant improvement in task performance (reading comprehension) and information recall. Explicitly assigning these roles to students may guide their learning process, encouraging the use of particular cognitive strategies (e.g. clarifying, predicting) in the classroom practice. It may also make students more metacognitively aware, or more aware of their own thinking processes. Would simply making students *aware* of such roles, rather than specifically assigning them, improve a student's perceived success of a teaching method? Simply stating learning goals does not always translate into student action unless the assessments in the course are directed at the stated objectives (Resnick, 1992). Indeed, explicitly stated skill learning objectives, although not equivalent to the cognitive roles of Brown and Palinscar (1989), have been used with variable success in medicine to guide medical student learning.

Use of an explicit list of skills for learning in clerkships has been shown to improve student perceptions of the clerkship's successfulness while simultaneously decreasing the anxiety of students about their success (McCurdy et al., 1995). In one study, students reported gaining a sense of accomplishment as they completed a checklist of relevant skills. In addition to improving students' perceptions of their learning, the skill list focused faculty teaching towards the stated set of skills that the students were to acquire during the clerkship. This improved the completeness of teaching by each clerkship mentor. The questions arises: Do students who feel like they learn more actually learn more? Or are they simply more comfortable in a learning environment where they are given explicit criteria to follow rather than a hidden or ambiguous standard to meet? It is possible that explicitly stated expectations of skill acquisition improves student understanding of the learning strategies and skills that they are expected to develop.

Explicitly stated objectives must be actively used by faculty and students in order to encourage learning, but do not necessarily guarantee improved quality of learning. Wyte et al. (1995) provided an explicitly stated list of learning objectives to both fourth year medical students during their Emergency Department (ED) rotations and interns in the ED. Neither group showed any significant change in performance on problems requiring either simple recall or complex synthesis (Wyte et al., 1995). However, making students more aware of the cognitive expectations of a teaching method may not actually improve performance as measured by conventional assessments. Assessments are often geared at measuring educational outcomes that are more quantifiable, such as information recall and simple concept application, rather than assessing complex cognitive performance (Moss, 1994). Explicit cognitive learning goals seem to have two requirements: (1) they must be understood and used by the learner in the classroom practice; and (2) they must be included in assessments of student performance.

E. What skills can the medical student acquire?

Setting explicit cognitive skills for the PBL classroom is thus more complex than superficial appearances may seem. By defining explicit skills for the student to pursue, one hopes that the novice will practice the skills that are evidenced by expert physicians. For example, a novice who pursues domain knowledge while practicing the skill of identifying and critiquing information resources is learning content knowledge while practicing a skill essential to the expert in his or her decision-making process (as in Barrows, 1988). However, while such cognitive skills may appear to be similar for both novices and experts, the actual cognitive process of problem-solving for the expert are different from that of the novice (Patel, Arocha, & Kaufman, 1994). The novice does not use a more simplistic version of expert reasoning. The two modes of reasoning are substantially different.

While skills such as "problem-solving" and "diagnosing and treating disease" from the Pew study above seem to fall under the umbrella of "clinical reasoning", these remain largely uncharacterized processes. Other characteristics such as "communicating effectively" and "pursuing a lifetime of continuous learning" are important sets of cognitive skills for students to acquire. However, these do not directly address the question -- what exactly changes as a novice pursues expertise?

IV. Clinical Reasoning

Having established a framework for creating cognitive skill objectives, we must now define the actual skills that might fit into undergraduate medical education. The first part of the following discussion focuses on models of clinical reasoning. We will look at how experts and novices construct and use basic science knowledge in their reasoning processes. The discussion concludes with a brief overview of the effects of PBL versus conventional curricula and, more specifically, how models of clinical reasoning limit what may be explicitly teachable in undergraduate medical education.

A. The hypothetico-deductive model of reasoning

Cognitive science from the 1950s to the 1970s theorized expertise to be dependent upon the problem solving strategies rather than knowledge (Newell & Simon, 1972). The hypothetico-deductive model as applied to medical problem-solving proposed that experts generate hypotheses based on the initial data of a given problem (Elstein et al., 1978). This required using a "mixed" approach to problem solving, requiring both the use of present knowledge and the acquisition of new knowledge. Hypotheses guide one's search for new data in a directed fashion. Used in this sense, hypothesis generation provides the problem-solver with a limited, manageable set of competing possible solutions to the problem. Both novices and experts make hypotheses during problem-solving; however, the hypotheses of the expert are of higher "quality" than those of the novice. One uses the problem data to weigh the likelihood of individual hypotheses. Hypotheses are ruled in or out based on how well or poorly each new datum supports them. Eventually, one hypothesis rises to the top of the initial set, rendering the final diagnosis.

The intent of PBL is to stimulate the acquisition and use of basic science knowledge through problem-solving in a clinical context. Learning occurs through a process akin to the hypothetico-deductive model of reasoning. PBL relies upon the cyclic process of data analysis, hypothesis generation, hypothesis-guided learning, and hypothesis selection. Although the main focus of the learning is directed at coverage of the basic sciences and not clinical diagnosis, students nevertheless learn the basic sciences in the context of a problem.

Several advances in cognitive science questioned this model of reasoning as the basis for expertise. Research in the 1980s on artificial intelligence put a dent in this theory as it became increasingly apparent that intelligent systems required a broad knowledge base as well as strategies with which to apply knowledge (Elstein, 1995). In studying the use of expert heuristics (Elstein, 1978), it was shown that teaching strategies to novices did not improve their problem-solving accuracy or speed. In addition, expert strategizing was not found to be constant across domains of knowledge: there was no general strategy used by experts, but rather multiple, case-specific strategies that involved the problem representation by the expert (Elstein, 1995). Both successful and unsuccessful clinicians used hypothesis generation as a strategy in problem-solving. This harkens once again back to Bruner's model of learning in which one alters learning strategy according to the context of learning. In the context of problem-solving, different problems may require differ strategies for their solution. In other words, not all problems are created equal. Thus it seems that the difference between experts and novices (or successful and unsuccessful "experts") lay in the quality of the hypotheses that drove problem-solving rather than the strategy of creating the hypothesis itself. This quality, in turn, seemed to depend upon the quality of the knowledge base that informed hypothesis generation.

B. Clinical Reasoning: Expert versus Novice

Clinical reasoning most basically is the ability to organize patient information with the intent to diagnose, treat, and manage illness. Higgs and Jones (1995) break clinical reasoning down into three interdependent processes: the use of knowledge, the act of thinking (cognition), and the process of metacognition (monitoring one's own cognition). Thus, attaining clinical expertise is not wholly the pursuit of knowledge. First, Higgs and Jones refer to the *use* of knowledge, not simply the possession of knowledge. Whitehead termed learning as the acquisition of the utilization of knowledge: achieving a state in which one is capable of applying knowledge to a situation. Clinical reasoning as defined above, is in part, the embodiment of this definition -- the *use* of clinical knowledge. Is it enough to simply supply knowledge in undergraduate medical education? A heavy reliance on teaching information, without a concomitant emphasis on the skills with which to practice and update that knowledge, is unwise considering that less than one-half of that knowledge may be true and useful by the time the student practices medicine (Armand et al., 1996).

Cognitive science theory proposes that information from a given problem is stored in packets, or "chunks", that are represented in memory. Theories conflict about exactly how the data are stored. Whatever its form, the representation somehow stimulates hypotheses about how the data relate together. In medicine, a set of signs and symptoms would stimulate the generation of hypotheses based on disease prevalence and mechanisms of disease which, based on new information as the problem continues, would be qualified and distilled into a differential diagnosis and, eventually, a working diagnosis (Kassirer & Kopelman, 1991). The limitation of short term memory to storing 5 to 10 items at one time restricts the number of hypotheses that one can entertain (Kassirer & Kopelman, 1991). Physicians are thought to gather new information in a directed fashion that permits collection of relevant data within the context of the problem rather than simply accumulating enough facts to make one diagnosis most likely (Patel, Arocha, Kaufman, 1994; Kassirer

& Kopelman, 1991; Patel & Groen, 1986). Accounting for multiple manifestations of diseases, both rare and common, requires a broad knowledge base. Thus, in order to reach clinical expertise, the novice must acquire sufficient knowledge of the prevalence and mechanisms of disease to permit directed information gathering in a way that maximizes his/her use of a limited short term memory space.

In terms of knowledge, medical expertise can be thought of as involving two sets of knowledge: knowledge of the basic sciences (e.g. knowledge of domains such as anatomy, physiology, and histology) and clinical knowledge (e.g. knowledge of associations between symptoms and diseases, variations in disease presentations, and treatment options). Patel and Kaufman (1995) believe these sets of knowledge to be distinct, both in the modes of reasoning and in the structuring of knowledge in each domain:

> Clinical knowledge is based on a complex taxonomy which relates disease symptoms to underlying pathology. In contrast, the biomedical sciences are based on general principles defining chains of causal mechanisms. Thus, learning to explain how a set of symptoms is consistent with a diagnosis may be very different from learning how to explain what causes a disease. (p. 126)

Research has shown that clinicians use little basic science knowledge in their explanations of clinical cases (Boshuizen & Schmidt, 1992; Patel et al, 1989; Patel & Groen, 1986). However, when faced with clinical problems that are difficult to understand or diagnoses with uncertainty, clinicians seek out new basic science knowledge in solving the problem (Joseph & Patel, 1990, Patel et al., 1990). The use of basic science knowledge has been described as inversely proportional to one's degree of expertise (Boshuizen et al., 1988). This begs the question: if basic science knowledge is not directly related to expertise in clinical reasoning, then why are experts consistently more accurate than novices in their diagnoses?

Experts and novices use biomedical knowledge differently. While the declarative knowledge of basic sciences may not be quantitatively different between novices and experts (Kassirer and Kopelman, 1991), the organization of that knowledge is. Patel, Arocha, and Kaufman (1994) state:

> ...experts and novices differ in their use of basic science.... For example, we have found that the coherence of an explanation is often reduced when basic science concepts are employed [by the student]. That is to say, the overall explanation becomes fragmented into discrete and isolated chains of inference, some correct, others partially correct, and others incorrect. The evidence also suggests that students possess substantial inert knowledge that frustrates their ability to apply specific biomedical concepts to clinical problem-solving tasks. (p. 191)

The accuracy of clinical reasoning depends on certain qualitative aspects of one's knowledge base (Elstein, 1978). Novices taught heuristics (rules of thumb) to solve clinical problems show no improvement in diagnostic accuracy. The accuracy of expert reasoning is due at least in part to a knowledge base organized around principles that permit rapid recognition of particular significant problem features (Patel & Kaufman, 1995).

In the development of expertise, the student clusters related concepts in a process that Boshuizen and Schmidt (1992) term "knowledge encapsulation". Links made between concepts (i.e. between peripheral edema and right-sided heart failure) result in nesting of such concepts together in related groups. This nesting results in a large network of hierarchically organized concepts. Connections proliferate with the accumulation of clinical experience. Eventually, so many "encapsulated" sets of concepts are present that they become "illness scripts". These scripts are activated when certain constellations of signs and symptoms are present and guide further clinical assessment. A given problem might activate several illness scripts from which one is chosen after new data is gathered along the lines of the scripts activated initially. Clearly, this sort of "matching" exercise requires an extensive and well-organized knowledge base. Patel and Kaufman (1995) believe this encapsulation process to be idealized, noting that basic science knowledge is used differently by different clinical domains. For example, while radiology requires a detailed knowledge of anatomy for diagnosis, cardiology relies more on the clinical associations built upon basic science knowledge rather than basic science knowledge in and of itself. Whatever the case, the expert's thinking does not always delve to the level of basic science concepts. It relies upon both causal basic science reasoning and associative clinical reasoning. Often these modes of thinking may not be coincident or dependent (Patel, Arocha, Kaufman, 1994; Boshuizen & Schmidt, 1992). Indeed, detailed use of biomedical information can actually interfere with clinical problem-solving (Patel, Evans, & Kaufman, 1990). With this background on how biomedical knowledge relates to clinical reasoning, let us turn to characterizing the cognitive processes that make an expert from a novice.

1. Forward versus backward reasoning

As their names suggest, these reasoning processes proceed in opposite directions. Both involve data, such as that given in a clinical problem, and hypotheses relating to those data. Forward reasoning is "data-driven", proceeding from data to hypotheses. This requires a strong knowledge base since the quality of the hypotheses generated is wholly dependent upon one's knowledge of the potential solutions to the problem. This method is fast and is characteristic of expert reasoning. Patel and Groen (1986) studied cardiologists' explanations of cases and found that their reasoning tended to proceed from the text of the case directly to a limited set of hypotheses (often only one). From this set, they chose a correct diagnosis. Forward reasoning can be very error-prone because it depends heavily upon one's present fund of knowledge to weigh signs and symptoms against each other, selecting the most specific and significant from the case to generate hypotheses (Patel, Arocha, and Kaufman, 1994).

Contrasting the expert, novices use backward reasoning. This process is "hypothesis-driven" moving from hypotheses to data-gathering. Little prior knowledge is required since one uses hypotheses to gather new data. One then uses the new information (in the form of basic science or clinical facts) to prioritize one's hypotheses accordingly. However, the quality of the final list of hypotheses is dependent upon the initial list generated from the problem data. Given the lack of experience and knowledge guiding a novice's initial hypothesis generation, the set of hypotheses that the novice works with are generally less accurate than those of the expert. In addition, because one relies on working memory to capture new data and compare hypotheses, backward reasoning is slow and effortful compared to forward reasoning. In being slow and methodical, backward reasoning is favorable, even for the expert, in situations of uncertainty (Arocha et al., 1993).

2. The "connectedness" of expert knowledge permits forward reasoning

Cognitive research has clearly demonstrated that content area knowledge plays a central role in all forms of reasoning, thinking, and learning (Resnick, 1987). The expert has highly efficient ways of representing a problem's information in his/her working memory (Patel, Arocha, & Kaufman, 1994; Groen & Patel, 1991). Retrieval of information from long-term memory is normally slow. One can conceive of the expert's knowledge base as being organized in long-term memory by a set of production rules (i.e. if-then statements), whereby symptoms trigger one or more potential diagnoses. For instance, the appearance of high fever, shaking chills, and night sweats together may stimulate the expert to immediately pursue a work-up for septicemia. The expert must use the patient's presentation, age, community contacts, etc. to guide his or her search of long-term memory to recall the potential microbes involved. The efficiency of this process depends in part on the clinician's ability to recognize patterns amongst the patient's data and how these patterns relate to underlying pathology.

Concepts or principles learned from solving particular problems are associated with two different sets of features (VanLehn, 1996): (1) superficial features that are a part of the problem but not causally or logically related to the solution (e.g. the name of a patient in a clinical case concerning fever and chills); and (2) structural features that are essential to the problem's solution and are, therefore, generalizable (e.g. the fact the fever and chills can be caused by bacterial infection). A learner initially associates all principles learned from problem-solving with *both* of these feature sets. The appearance of superficial features will trigger the retrieval of the associated concept from long-term memory. In the process of generalization through experience (VanLehn, 1996), the learner deletes superficial features from this cueing process so that only structural features (fever and chills in another patient case) will trigger the retrieval of a linked concept (bacterial infection). Whereas knowledge in the novice is cued by both superficial and structural features, experts take advantage of a knowledge base already organized by the generalization process. The much sought after "clinical pearls" may be examples of structural features of clinical problems that are highly specific to particular clinical principles.

The term "skilled memory" has been applied to the expert's highly organized long-term memory (Kassirer & Kopelman, 1991). Its organization permits access more akin to that of short-term memory during problem-solving. As a result, the expert's long-term memory becomes an effective extension of short-term memory. The expert uses this knowledge base to help direct the collection of new data about the problem based on the problem's structural features. This type of thinking is typically characterized by applying the rules that organize one's knowledge to a given set of facts to produce a solution (Groen & Patel, 1991; Newell, 1988). Part of this knowledge base is a set of "illness scripts" that are thought to be descriptions of previous patients or summative prototypes of illnesses that the expert has accumulated with experience (Kassirer & Kopelman, 1991). Research in cognitive skill acquisition supports the value of examples to the development of expertise (VanLehn, 1996).

3. Novices explore new domains with backwards reasoning

Unlike the expert, the novice's knowledge base is constrained by limited domain knowledge. It is not as complete nor as well organized as that of the expert. The novice has few, if any, illness scripts. Thus, s/he must build causal models of pathophysiology to drive the problem-solving process in linking from signs and symptoms to potential diagnoses (Kassirer & Kopelman, 1991). Lacking in pathophysiologic knowledge, the novice must construct a knowledge base in the context of the problem's data and then use that new knowledge to generate and choose among hypotheses (backwards reasoning). Contrasting the directionality of the expert, the novice moves back and forth between knowledge and problem facts, generating and prioritizing hypotheses (Groen & Patel, 1991; Newell, 1988). VanLehn (1996) models the novice as working towards an "intermediate phase" of learning, where s/he begins to generalize (as above) principles gained from problem-solving. In this sense, problem-solving permits the learner to work out bugs in associations between problem features and clinical principles. Unfortunately, this process is extremely time-intensive. Interestingly, experts will use backward reasoning when their knowledge base is insufficient to lead to a problem's solution (Groen & Patel, 1991). In this case, one might think of the expert as having to employ backwards reasoning because his or her knowledge base is in a different domain. As a "foreigner", the expert may have to explore the new domain as a generalist. The expert's knowledge base is of some use in providing a general fund of medical knowledge. However, this knowledge base is not organized in a way to be sensitive enough to pick up on domain-specific patterns of disease, leaving the expert to work with a mixture of forward and backward reasoning.

4. The transition from novice to expert

The ability to perceive large meaningful patterns in a given domain requires (1) knowledge of the domain's content and (2) familiarity with the relationships among the concepts of the domain. For example, it would not be enough to know that mast cell degranulation causes an allergic response. One would also need to relate, or connect this fact to the cytokines involved in anaphylaxis and the cytokines responsible for the wheal and flare reaction, both of which are triggered by the mast cell. Cognitive research to date supports the idea that expertise is built upon many cycles of learning sets of small pieces of knowledge (e.g. facts, concepts, heuristics). As those pieces of knowledge are constructed and generalized individually, one's knowledge base becomes more and more integrated in a hierarchy of related concepts. This hierarchical structure permits more forward reasoning and, hence, greater speed and accuracy in problem-solving (VanLehn, 1996). The pathway to expertise in this sense is paved with a very elaborately connected knowledge structure.

Expert problem solving thus depends partially on one's biomedical knowledge. As we have seen, knowledge alone does not make an expert. One must employ the cognitive skills that shape and organize the expert's knowledge in such a way as to enable forward reasoning. Traditionally, learning the clinical problem-solving process has been left to observation of others engaged in the process (Kassirer & Kopelman, 1991) Clinicopathologic conferences[3] , while descriptive of an expert's considerations in solving a problem, suffer from retrospective bias: the problem-solving process is clarified by fore-knowledge of the outcome (Kassirer & Kopelman, 1991). Various other teaching methods have been proposed for teaching clinical reasoning (Kassirer & Kopelman, 1991; Barrows, 1988). Learners use backward reasoning in the classroom to solve clinical problems.

[3] Clinicopathologic conferences are stepwise reviews of the presentation, history, and work-up of a patient, usually leading to a specific diagnosis.

Teaching clinical reasoning strategies alone does not improve novice performance (Elstein, 1978) Encouraging skills that stimulate knowledge organization and re-organization seem likely to foster the connectedness that expert's rely on for forward reasoning. The discourse of learning in PBL, however, is directed by backward reasoning and contains many misconceptions initially. Thus, the student's informational learning task is two-fold: to learn the content of the domain and to resolve any misconceptions. Both must be met before the students possesses a valid understanding of the material.

Groen and Patel (1991) relate the educational value of these misconceptions to the type of reasoning that the learner uses to solve the problem at hand. In the context of forward reasoning, one's misconceptions may be seen as adequate for the solution of a problem. The student forcibly applies an inadequate knowledge base to the problem without re-considering his/her knowledge in light of the problem's information. Lacking the abstract rules and concepts of the expert, the learner's inferences will invariably lead to erroneous conclusions in problem-solving (Patel, Arocha, & Kaufman, 1994). Backward reasoning may challenge these misconceptions and force the learner to modify them. Through repeated challenging and updating of one's knowledge base, one may be generating the rules that organize and govern expert knowledge. Groen and Patel (1991) conclude:

> The important part of learning may consist in testing and pondering the adequacy of one's explanations rather than achieving accurately implemented solution procedures. If this is so, then a greater instructional emphasis on explanation rather than problem solving might prove profitable. The "problem-based learning" we mentioned at the beginning of this paper might at least be supplemented by "explanation-based learning". (p. 43)

Explanation requires refining the knowledge relating to the problem at hand. In solving a problem, new knowledge gained is still specific to that problem; in other words, the structural features of the problem may still overlap with superficial features which potentiate incorrect application of the newly learned principles. Until the learner differentiates between superficial and structural features associated with the new knowledge, those principles will not be generalizable.

"Explanation-based learning" has been shown to greatly improve problem-solving ability. Chi et al. (1989) studied students who explained texts to themselves, making inferences about textual examples beyond the information given in the example. These students showed significantly superior problem-solving ability when compared to students who simply read the information and examples given. The authors proposed that making these inferences helped to fill in gaps in student knowledge left from the incompleteness of the text in two ways: (1) encouraging retrieval and application of previously learned concepts; and (2) actively encouraging the process of generalization described above when students attempted to extrapolate from an example in the text to other hypotheticals using self-explanation (Chi & VanLehn, 1991). This self-explanation effect has been shown in a variety of task domains (VanLehn, 1996). Explanation may help in the de-bugging process of new knowledge, promoting correctly directed retrieval and application. However, cognitive research has yet to find out whether such explanations may be of benefit in these classrooms (VanLehn, 1996).

Ideally, one would hope that knowledge of the cognitive skills that underlay expertise would define a specific set of cognitive skills that one would want learners to practice in their acquisition of knowledge. By explicitly stating these skills, one might encourage their use by the learners as learning strategies in the domain throughout the transition from novice to expert. Unfortunately, expertise is not characterized well enough for this to happen. At present, clinical expertise and cognitive skills seem to depend heavily upon the breadth and connectedness of the one's knowledge base. Given the differences in the directionality and knowledge-dependency of problem-solving in novices and experts, teaching clinical reasoning as a skill *itself* implausible.

While both PBL and conventional curricula attempt to provide a knowledge base to students, they do so in very different ways. PBL relies on the assumption that learning basic science in a clinical context will stimulate the use of cognitive skills similar to an expert. As the learner applies new knowledge with cognitive practices extrapolated from expertise (as in Barrows, 1988) s/he begins to approximate expert thinking. In contrast, traditional, 2 X 2 curricula have less clinical contextualization, choosing to focus on establishing a broad, abstract knowledge base to ground future clinical learning. The next section will compare these two curricula in terms of the cognitive practices that they engender.

C. Teaching medical expertise: PBL and Conventional Curricula

Both problem-based learning and conventional curricula approach teaching the same fund of basic science knowledge from two different angles. While the latter focuses on broad informational learning in abstracted formats, the former emphasizes informational learning as it pertains to clinical problem-solving. The motivations for using PBL curricula in medical education are several fold: (1) fostering problem-solving skills in students; (2) to enhance acquisition, retention, and use of knowledge by students; (3) to bring learning of the basic and clinical sciences in closer proximity to one another; and (4) to foster "self-directed learning" (Norman & Schmidt, 1992). As stated above, the use and success of PBL is highly dependent upon the instructors who guide interaction and the students themselves. Meta-analysis of PBL curricula has shown that while students find PBL more enjoyable, their basic science knowledge may be limited with respect to their counterparts in the conventional curriculum (Albanese & Mitchell, 1993). Performance on nationally standardized exams varies between different PBL curricula when compared to conventional curricula. This variation may reflect the effect of the variability in tutor and student abilities in the classroom (Albanese & Mitchell, 1993). One study comparing PBL and conventional curriculum students showed that PBL students performed worse on the USMLE I, equally as well on the USMLE II, and superiorly on the USMLE III (Mennin et al., 1993). Whether the NBME's assessments are sensitive for cognitive skill acquisition is not known.

Research has shown that students in conventional, lecture-based medical curricula organize their basic science and clinical knowledge differently compared to students in PBL curricula and that these differences last into residency (Patel et al., 1991; Patel et al., 1993). Conventional curriculum students, unlike PBL students, tend to separate their knowledge of basic science and clinical reasoning. These students tend to use their basic science knowledge only when solving a clinical problem that does not conform to conventional clinical presentations. PBL students, on the other hand, integrate their basic science and clinical knowledge as they learn from problems. This learning in the context of specific problems can result in an inability to decontextualize basic science concepts from particular clinical presentations (Patel et al., 1993). A problem does not guarantee that concepts learned from different portions of a problem will be integrated to form a functional network of basic science concepts. Dolmans et al. (1993) state that problems should match the students' levels of previously acquired knowledge and be open-ended enough to stimulate discussion. Learning is thus dependent not only on the quality of the objectives for the classroom, but also on the substrate for learning itself.

The continued use of biomedical knowledge in a backward directed fashion in residency shows that the effects of PBL reach outside of the undergraduate medical curriculum (Patel et al., 1993). PBL residents appear to use less forward-directed reasoning in their clinical problem-solving. However, forward-directed reasoning in clinical problem-solving may develop as a result of the specific organization of clinical concepts with little or no biomedical science information (Patel, Arocha, & Kaufman, 1994; Patel & Groen, 1991). This latter point supports the "two-world" hypothesis of

Patel and Kaufman (1995) referred to earlier. The worlds of clinical medicine and basic science may involve not only different bodies of concepts, but different modes of reasoning as well. Are PBL students at a disadvantage compared to conventional curriculum students if they continually attempt to draw upon basic science causality for clinical reasoning? Arguments have been made that PBL's contextualization of the basic sciences may restrict the transfer of that knowledge to a diversity of clinical situations (Patel, Arocha, & Kaufman, in press). The PBL student, in returning continually to basic science causality, may be expending cognitive resources that a conventional curriculum student might reserve for drawing simple clinical associations. More research is needed to explore this tentative hypothesis.

Overall, clinical reasoning is complex and poorly understood. While it is possible and beneficial to identify cognitive skills that a teaching method encourages, these skills will not explicitly relate to the actual cognitive processes of expert clinical decision-making. Rather, they may refer to learning strategies and problem-solving techniques that aid learners in developing their own knowledge base and in using that knowledge in various contexts. PBL emphases both of these objective equally, encouraging active student learning in clinical contexts. Despite reasonable arguments made in support of PBL, there exists little research documenting its cognitive effect on the development of medical expertise by medical students.

V. Summary

The introduction of PBL to medical education was, in part, the result of an attempt to bridge the gap between basic science learning and clinical reasoning in UME. Learning basic science concepts through their application to clinical contexts seemed likely to approximate the cognitive skills that experts require in their solutions of problems. In understanding PBL, it is necessary to understand the cognitive skills that it encourages its students to use. Time spent by students on cognitive skill acquisition detracts from the pursuit of broad domain knowledge. This broad knowledge is the traditional Flexnerian objective of the pre-clinical years. PBL stimulates skill acquisition in addition to knowledge acquisition. Educational expectations of an instructor and students often differ. An explicit dialogue about the intended cognitive skills to be acquired by the student may improve learning of those skills.

The congruence between the cognitive practices that PBL encourages and the cognitive practices of the expert clinician is unknown. Cognitive science research has shown medical expertise to be highly knowledge-dependent. Expert reasoning proceeds from problem data to a limited set of hypotheses that guide further data collection. This process is fast and highly accurate. Novices tend to work backwards from problem data, creating a set of hypotheses that guide their acquisition of new knowledge. This new knowledge is then used to rule in or out various hypotheses. Because of the novice's limited knowledge base, the hypotheses generated are less accurate than those of the expert. The novice's backwards reasoning process makes learning by problems much more time-intensive. Whether PBL is superior to conventional curricula in cultivating medical expertise is unknown. In conventional curricula, students demonstrate less integration of basic science and clinical knowledge. PBL students, on the other hand, tend to use basic science explanations more often in their clinical problem-solving, but seem to have difficulties de-contextualizing basic science knowledge from the pedagogic clinical cases.

Given our limited understanding of the relation of basic science knowledge to clinical expertise, we can conclude little about the "best" medical educational methods. Rather, a diversity of teaching methods provides the learner with multiple contexts to which s/he must adapt cognitively in order to succeed. While lecture-based teaching focuses on abstracted basic science concepts, PBL encourages learning basic sciences in context. Both instructional methods have their theoretical strengths and weaknesses regarding their abilities to cultivate expertise in the learner. The author places emphasis on the fact that these attributes of teaching methods are *theoretical*. They are based upon constructed models of how we think the experts think and what preparation is essential to reaching that level of performance. Only as educational research continues to characterize these methods and their effects can we, with any grounded certainty, say that a teaching method does what it is intended to do. The intention of this paper is to characterize the Small Group Process teaching method. Based on this background, the paper now turns to exploring one form of PBL, SGP, with two intentions: (1) to characterize the cognitive skills that SGP stimulates learners to practice; and (2) to understand the cognitive value of the method in fostering the pursuit of medical expertise.

Chapter Two: Methods

Since the pathway between novice and expert cognition is unclear (Van Lehn, 1996), we are left to characterize these end-points and interpolate much of the learning process. The preceding literature review has described an apparent dependence of expert medical problem-solving upon a well-organized knowledge base of clinical and basic science concepts. A learner must therefore not only take in new pieces of information, but assess their validity and generalizability in order to structure his or her growing knowledge base. As this fund of knowledge changes, so does the reasoning process. As more concepts are connected in a hierarchical fashion, the learner may proceed directly from particular problem data (e.g. symptoms) to potential diagnoses with increasing accuracy. With this transition to forward reasoning, the learner achieves expertise.

The aims of this study are not to further characterize the novice or expert, but rather to examine a particular learning process thought to foster the knowledge, skills, and attitudes that contribute to clinical expertise. This study fostered the creation and use of cognitive skill objectives to evaluate a problem-based classroom. Survey data on the students' self-reported learning styles was also collected in an attempt to better define the learners in the class. Superordinate to these data is the cognitively-based video and audio tape analysis of the actual classroom process. The purpose of this analysis is to improve our understanding of small-group, problem-based learning in medicine. Before describing the methodology in detail, some background on the setting of this research is needed.

The Joint Medical Program is a five year MS/MD medical curriculum. Every year a class of twelve students begins a three year course of study at the University of California at Berkeley. During these three years, the students work in a variety of teaching methods to learn the pre-clinical medical curriculum as well as pursue a Master's degree in a healthcare-related field of choice. Among the program's mission goals, the following are most germane to this discussion and research (JMP, 1996):

> A commitment to exemplary education in the basic sciences and the practice of evidence-based medicine
>
> An orientation towards cooperative, case-centered, small group learning
>
> A responsibility for fostering the self-reflective growth of individual students (p. 1)

The teaching method that this research focuses on is Small Group Process (SGP), a cooperative, problem-based teaching method that is described in the following section. The purpose of this research is to describe this teaching method. My aims are not to confirm hypotheses about the method, but rather to identify some of the cognitive features of it.

I. Participants and classroom structure

Research was conducted on the 12 students composing the 1994 first-year class of the University of California at Berkeley/University of California at San Francisco Joint Medical Program (JMP). The class was a basic science course entitled Neurobiology and was taught using a Small Group Process (SGP) format.

This teaching method centers around student-driven discussion of basic science concepts relating to a set of clinical cases. Students must cooperatively discuss the problem(s) that the case presents, create hypotheses regarding the pathophysiology of the case, determine learning issues (topics for further study out side of the class), and apply their basic science knowledge to the case at the end of the class. Typically, one class is composed of two separate sessions. In the first session, students see the problem for the first time and generate hypotheses and learning issues (LIs). They then pursue these topics (usually basic science topics relating to the case) in the time between the first and second sessions. At the second session the students discuss their learning issues and, if time permits, apply the new-found basic science concepts to the clinical case. This process continues in a cyclic fashion for the entire term. The assumption is that the students cover the domain's knowledge (i.e. physiology, neurobiology) by completing the case descriptions.

At the beginning of each session students "check-in". Each of the students gives a brief statement of how they are doing in school, how they are feeling, how interesting they found the learning issues, or some other issue important to them. Classes end with "check-out" when the students critique themselves and the group on how well they thought the session went, suggest any improvements in the group process, content coverage, etc.

The tutor's role in the process is to ensure that students cover the domain knowledge in a timely fashion and that the concepts discussed by the students are indeed correct. To aid in monitoring the group's progress, one of the six students in a group plays the role of facilitator. The facilitator's job is to ensure that the group sets learning goals for the class period and keeps pace in achieving those goals. While the direction of the discussion is often driven by the group, the facilitator may re-direct the group to more pressing issues or topics if the group has set those topic(s) as goals or assents to the facilitator's recommendation.

The twelve students in the study had previous contact with the SGP teaching method through the Physiology course taught by the same professor in the Fall semester. The Neurobiology course is taught using an identical teaching method in the Spring semester. The Neurobiology course divided the main topics of neurobiology into paper problems. The students were divided into two groups of six and each group had a tutor (clinical physician). In keeping with the SGP format, each problem was divided into two sessions. In the first session, the students generated hypotheses about possible causes for the patient's problems and they also generated six learning issues. Each member of the group was responsible for reading about all six learning issues. However, the students would take one learning issue each to learn in more depth, thereby making them the resident "expert" in that issue as they related to the problem in the second session as the students discuss learning issues. At the end of the class, the basic science knowledge covered by the group is used in an attempt to arrive at a diagnosis of the patient's problem. At the end of the second class, students divide up the learning issues from this class and choose one each to review and write-up formally.

All students gave informed consent to all of the following research methodology under the UC Berkeley CPHS guidelines (see Appendix A for informed consent document). During both the collection of data and the ensuing analysis, all data has been kept confidential and secured.

II. Skill-oriented learning objectives

At the beginning of the semester, a workshop (see Appendix B) facilitated by the author had the students create a list of cognitive and interpersonal skill objectives that they wanted to develop over the course. Independently, the instructors of the course also developed a list of skill objectives for the class based on the same questions. These skills were compiled into a master list composed of both sets of objectives and were distributed to students and instructors for reference during the term (see Appendix C).

III. Student evaluations of course success

Daily evaluations were required of the students. These evaluations consisted of several questions based on a seven-point, bipolar Likert scale. The purpose of these evaluations was to get a general perspective on how well students perceived the success of particular sessions. This information was used to select video and audio tapes for discourse analysis.

The skill objectives that both students and instructors created were incorporated into a quantitative and qualitative course evaluation distributed at mid-term (MT) and end-of-term (ET) (see Appendices D and E). The qualitative sections of the evaluations consisted of two global questions regarding how well the course was meeting their educational needs. The quantitative sections required the ranking of how well the course was fulfilling the stated skill objectives on a five point, bipolar Likert scale. There was space given for open comments on each objective, but was not required. Students' qualitative and quantitative feedback was transcribed into an anonymous master list (see Appendices F and G) and given to the instructors to inform changes in the course's design at mid-term. Copies of these results were also distributed to students for their review. The main change at MT was the increasing of the time allocated to the second session (when learning issues were discussed) and the reduction of the time of the first session.

The ET evaluation was identical to the MT evaluation except for two additional sections. First, a set of four questions was added to the evaluation to assess the impact that the MT evaluation had on the class structure. The questions were on a five point Likert scale and had space for open comments if student so desired. These data were compiled and presented anonymously to both instructors and students. The second additional section contained the learning style inventory which is discussed in the next section.

As with any evaluation, the responses reflect the thoughts of a given student at a point in time. As such, they are somewhat subjective and do not necessarily reflect the student's feelings about every day of the course. Rather, these are reflected averages that the student is recalling based in part on the experiences of the day that the evaluation was written. In addition, differing interpretations of statements and Likert ratings among the students and between the students and the interpreter can disrupt the validity of the evaluations. Although great effort was taken to place all skill objectives derived by the students in their own words on all evaluations, one cannot rule out differing individual meanings of those objectives for each student.

IV. Learning style inventory

The students completed a learning characteristic inventory composed of fifteen bipolar scales adapted from Kolb's learning skills inventory (1984) (see Appendix H). The bipolar scales were converted into a numerical scale from 1 to 7 for the purposes of statistical analysis; the number 1 was arbitrarily assigned to the left handed pole and 7 to the right. Blinded alpha-numeric codes were assigned to all papers (MT evaluation, MT evaluation, and Inventory), permitting correlation of individual learning styles with the MT and ET evaluations. The evaluations and inventory data collected and presented in this paper are from all twelve participating students. This is in contrast to the video and audio analysis, in which only nine of the twelve students were studied.

V. Cognitively-based video and audio tape analysis

All class meetings were videotaped and audio taped. The purpose of this record of the group interactions was for discourse analysis of individual roles and group interactions in SGP. In describing the activity of the classroom, the convergent sources of video and audio taped interactions were used. The entire semester was watched once for variability between sessions and classes. Then two classes (each composed of a first and second session) were chosen for analysis. Each class had six students working together. Three of the six students were the same for both classes while another set of three students switched into the group for the second class. Thus, a total of nine students were studied (3 + 3 for the first class; same 3 + new rotation of 3 for the second class).

The classes were transcribed for discourse analysis (1.23.97 to 1.30.97 and 4.2.97 to 4.9.97). The transcripts were coded for (1) interactions and exchanges of propositions; (2) proposition content; and (3) group cognitive activity.

Analysis of exchanges was coded using both video and audio tape. Dyads were defined as exchanges between two people by directly addressing a person by name (audio) or by visual contact during comments (video). A "group" code was designated for exchanges that were not directed at any one individual. Interactions were summed for both group-directed and dyadic exchanges for both classes. Total sums for each class and both classes together were also calculated.

Analysis of proposition content was coded using the transcripts. "Content" was defined as a topic that was raised by the class and discussed with basic science or clinical concepts. Propositions had to contain basic science or clinical information as statements. This was interpreted as actual coverage of relevant content. Questions concerning basic science or clinical concepts that were not answered by the group or the instructor were not coded for their content since these statements did not contribute new knowledge to the group (see Appendix I for topic list).

Group cognitive activities were defined by analysis of the transcripts and audio tapes based on student interaction, subject content of statements, and the quality of statements made (i.e. rhetorical questions, statements of facts, statements of hypotheticals, answers to questions). Using activities previously identified by Brown and Palinscar (1989) in reciprocal teaching (clarifier, executive, contributor, summarizer, and note-taker), several similar activities were observed. Other activities in the SGP classroom not included in the reciprocal teaching model were identified and characterized based on the classroom process. The activities are listed below:

- planning the session - often referred to as "process"; involved setting time contracts, organizing session's activities, coming to consensus on activities or directions to take discussion.

- reading the problem - literally, time spent reading the paper case.

- defining/clarifying the problem - defining ambiguous terms in the case presentation, getting further contextual information about the patient, applying new knowledge to the case.

- hypothesis generation - creating hypotheses that might explain the case.

- hypothesis clarification - questioning what someone means by their hypothesis, understanding how the hypothesis may or may not relate to the case.

- learning issue generation - deciding on topics for further, outside study.

- learning issue clarification - questioning what someone means by their learning issue, creating a question that appropriately captures the topic to be researched, understanding what the presenter of a learning issue is meaning.

- learning issue review - review of the learning issues set at the end of last class.

- learning issue reporting - literally, didactic reporting of a learning issue's concept(s) to the group (contrasts the interactive nature of learning issue clarification).

- information requests - requests for basic science information or concepts that are not covered by either learning issues or by the problem (i.e. typical lab values, etc.)

• information given - student or tutor provides the information requested from memory or by looking it up in a reference text during the session.

• summarizing - communicating the sum of what someone or the group has said back to the group for verification of one's understanding or recapping progress that the group has made.

• tutor verification/asking questions - tutor assesses the understanding of the group by asking questions, postulating problems or situations, asking for consensus on understanding of a given concept or fact.

• tutor modeling - tutor demonstrates thinking processes explicitly to the group as an example of an expected action by the group.

Examples of excerpts of these activities are given in Appendix J. Activity codes were assigned to the transcript as the dialogue progressed throughout the two classes. The data was then summarized in narrative (sequence of activities) and temporal (activity sequence over time) formats. Particular exemplars were chosen for local coding of exchanges and propositions.

Chapter Three: Results and Discussion

The methods of studying the classroom provided both quantitative and qualitative perspectives on the Small Group Process teaching method. Both students and instructors reflected on their intentions for learning in the classroom by creating learning objectives centered around cognitive skill acquisition rather than knowledge acquisition. These objectives were specific to the teaching method and varied between instructors and students. As the reader will see, both instructor and student objectives share many similar features with the more general lists of cognitive skills presented in the literature review (AAMC, 1984; Pew, 1991).

This study involves data from two main sources: (1) the surveys of students' and instructors' reflections on the learning process; and (2) analysis of the classroom process with audio and video transcripts. The evaluations data based on these objectives give quantitative measures of how well the entire class of twelve students felt the SGP teaching method encouraged skill acquisition. The students reported a heterogeneity of self-described learning styles. Correlations between these styles and the evaluations of the course showed four learning characteristics to be associated with positive evaluations.

While all of these data provide perspectives on the learning process from different sources, they serve as a proxy for the actual classroom practices. To characterize the actual cognitive work in the class, video and audio tapes of the classes were recorded for analysis. Quantitative and qualitative analyses of two classes provides a detailed account of what the students were cognitively engaged in during the learning process. This analysis permits comparison of SGP to models of goal-driven inquiry as well as to other studies of problem-based learning in medicine.

narrowed appreciably. This may reflect a convergence of the students' understandings of the objectives in the context of the classroom. This convergence might result in a common understanding of the classroom process's objectives by the end of the course. Four of the individual cognitive objectives increased by more than 0.5, while none decreased more than 0.1 indicating a general trend towards improvement in meeting the objectives.

The instructor-generated objectives and the students' evaluation of them at both midterm and the end of the semester are found in Table 2.

Table 2. Instructor-generated cognitive skill objectives and student evaluations of how well they were met by Small Group Process (1= "not at all, 5 = "very much").

Instructor-generated SOLO	Mean mid-term rating (SD)	Mean end-of-semester rating (SD)
Present knowledge in the context of specific Neurobiological problems	3.9 (1.0)	4.1 (0.90)
Use class meeting time to increase the perceived informational needs in a given area of Neurobiology	3.5 (1.0)	4.1 (0.67)
Have mutual respect with an understanding of how diversity of learning styles, etc. contributes to being a good doctor	3.9 (1.1)	4.2 (0.58)
Use self-directed study and information resources to meet the perceived needs raised in class	3.7 (0.89)	3.7 (0.89)
Set learning goals and evaluate progress towards those goals	3.6 (1.0)	4.2 (0.75)
Improve leadership skills in group work	4.3 (0.75)	4.3 (0.49)
Learn how to communicate complex concepts in simplified terms	3.8 (0.75)	4.1 (0.79)
Integrate knowledge into concise, understandable formats	3.5 (0.80)	4.2 (0.58)
Improve ability to build consensus and give peer review	4.2 (0.56)	4.2 (0.62)

For the instructor-generated cognitive objectives, the mid-term mean was 3.7 (SD = 0.52) and for the end-of-semester the mean was 4.1 (SD = 0.34). Unlike that of the student-generated objectives, improvement for instructor-generated objectives was significant ($t = 2.8$, $p < .02$). Objectives showing the greatest improvement between MT and ET were: (1) using class time to increased one's perceived informational needs in a given domain (17%

improvement); (2) setting learning goals and evaluating progress towards those goals (17% improvement); and (3) integrating knowledge into concise, understandable formats (20% improvement). As seen in the student set, the evaluations of the instructor-generated cognitive objectives showed not only a general trend towards improvement by ET, but also a narrowing of the standard deviations. This too points toward the possibility that students may be gaining a common understanding of the instructors' intended objectives during the course.

The products of both the student and instructor reflections on the cognitive skills relevant to the SGP teaching method are rich in content. SGP stimulates students to pursue a long list of cognitive skills in addition to the informational content of a domain. This shows that SGP shares some features with Ram et al.'s (1995) model of goal-driven inquiry. As the objectives indicate, SGP is experiential, opportunistic, diverse, and introspective. Focused around the reasoning task of problem-solving, students and instructors recognize the need to postpone certain learning goals for out-of-class study as learning issues. The instructors generated a diversity of strategies to base the learning process, including concept simplification, integration, and contextualization.

There was incomplete overlap between student and instructor perceptions of the cognitive skills practiced in SGP. Instructor and student perceptions of the classroom's activity differ. While the instructors' objectives tend to concern abstract cognitive functions (e.g. contextualizing knowledge, simplifying complex concepts), they do not directly refer to the students' objectives of handling large volumes of information and managing time efficiently. While the intentions of instructors may lean towards the application and use of knowledge, those of the student seem to be referencing the need to explore large volumes of information efficiently through the class. The instructors' intentions appear to reflect their support of active inquiry. Backward reasoning in problem-based learning restricts the content coverage of students engaged in truly active inquiry. This slow reasoning process takes time away from learning content knowledge which may frustrate the student's expectations of handling the large volumes of information within the domain. The student evaluations of this objective (mean = 2.75, SD = 0.91) seems to support this hypothesis. Other student skills tended to be more introspective. Being aware of one's own knowledge, managing time efficiently, and following the group's goals all relate to introspective, goal-driven inquiry but are not explicitly reflected by the instructor objectives.

Evaluation of SGP based on acquisition of cognitive skills can reflect how well the teaching method fosters those skills. It also allows students and instructors to understand each others' motivations in thinking. Perhaps making objectives explicit gives the student a set of learning strategies to work with as Bruner (1985) suggests. As the student comes to understand the cognitive intentions of instruction, they may become more metacognitive in selecting particular learning strategies to meet the instructor's expectations. The statistically significant improvement in evaluations of the instructor-generated cognitive skills over the semester seems to support this hypothesis.

II. Correlations between class evaluations and learning style responses

The students' mean evaluation of the course's success at the end of the term were used for Pearson R correlations between student self-described learning characteristics (see Appendix H) and their evaluations of the success or failure of SGP. Results showed that four of the bipolar scale items correlated significantly with evaluations. The statistically significant results are summarized below. Students who evaluated the course highly described themselves as:

- **Active learners** (#1), while students who rated the course lower tended to describe themselves as passive learners ($r = -.78$, $p < .01$).

- Students who rated the course higher tended to prefer to **build concepts interactively** (#6), while students who rated the course lower tended to prefer to model concepts in their heads ($r = .75$, $p < .01$).

- Students who rated the course higher tended to prefer to **use intuition** (#8) to guide their thinking, while students who rated the course lower tended to prefer to use existing concrete models to guide their thinking ($r = -.65$, $p < .05$).

- Students who rated the course higher tended to continually **re-evaluate their understanding** (#15) of concepts, while students who rated the course lower tend to be frustrated by discussions of concepts that they feel they already understand ($r = .74$, $p < .01$).

Kolb (1984) hypothesized that the majority of learners in medicine would be amalgams of all of four prototypes of his identified learning styles, thereby possessing a broad palette of strategies that would permit adaptability to multiple tasks. Hence, the medical learner is both assimilator and accommodator, both diverger and converger. However, it is interesting to note that the learners in this study showed significant variation in self-described learning style characteristics (see Appendix H). While the medical learner is indeed an adaptable learner, likely possessing many of the characteristics of Kolb's model, the medical learner (within the limits of this study) may not be adaptable *and equally successful* in any teaching method. The medical learner might have his or her own idiosyncratic set of learning preferences. These preferences may, in turn, affect the student's perception of his or her own success in a given teaching method.

Since the format of SGP is one of active participation in cooperative problem-solving sessions, a positive correlation between active learning and evaluation of SGP seems reasonable. Given that the distribution of the class was predominately towards the "active" pole (10/11 respondents), little can be said regarding the relation of a preference for passive learning to cognitive objective fulfillment in this SGP class (1/11 responding "slightly passive").

Interestingly, the "interactive" students perceived the course to succeed in helping them to meet their stated objectives. The "modeling" students, while learning from the *same* group process as the "interactive" students, felt that the process was less successful in meeting the objectives. Perhaps students who prefer to "model" concepts learn less information from a SGP classroom as opposed to a more traditional, lecture-based classroom. They may lack some of the strategies necessary for successful interactive learning. Having to acquire these new skills *de novo* may frustrate exploration of a new domain. Thus, not only may one's self-concept of learning dictate a preference for particular teaching methods, but it may also affect how well one learns in a given method as Witkin (1977) and Bertini (1986) have hypothesized.

Group process works on identifying "learning issues", or gaps in the students' knowledge of a domain. Often, one must continue with the problem-solving process having recognized and recorded a gap in the group's knowledge. Learners who have a lower tolerance for problem-solving without having sufficient domain knowledge (i.e. those describing themselves as needing existing, concrete models to guide one's thinking) may find SGP frustrating because of this need to press on with the case. This process of identifying learning issues repeatedly, however, is central to the completeness of coverage in a given domain. More "intuitive" learners, those able to use their present understanding of a domain to extrapolate beyond these deficiencies in knowledge, may be better equipped to bridge the gaps in their own understanding while keeping with the group's learning process. Learners preferring more "concrete" models of information to guide their thinking may be confused or frustrated by the SGP exploratory learning process (i.e. identifying multiple learning issues within the domain at hand). Content coverage in this process is directed by the creation of multiple learning issues, each without immediate resolution. The frustration of the concrete model learners may translate into lower evaluations of the SGP than those of the intuitive learners. The latter may have a learning style that is more adaptive for a learning environment that requires problem-solving in the face of multiple domain deficits.

The cooperative nature of SGP suggests that persons who use discussions of familiar material to actively review might evaluate this teaching method more highly than those frustrated by such discussions. Re-evaluation of understanding encompasses such skills as "communication (listening to others)", "to be aware of one's own knowledge", and "to be able to follow the group's goals". One would thus expect that a person coming to a SGP classroom with such a self-concept would actively exercise these skills, making SGP seem successful in meeting the skill objectives. The "frustrated" learners found the SGP method less successful than the re-evaluators. Two reasons might explain this difference: (1) in interpreting the objectives, the "frustrated" learners did not include the *specific* task of listening to repeated material; (2) "frustrated" learners did not find the SGP method helpful in acquiring these skills which they lacked upon entering the class.

These hypotheses regarding learning styles must be qualified by the small number of participants in this study. No statistical manipulation could make these hypotheses externally valid. Rather, these ideas are offered to the reader as reflections on the classroom with, at the greatest, internal validity.

III. Role of Evaluation in SGP

Students were uniformly positive about the utility of explicitly stating the instructor-generated learning objectives. They rated explicit objectives as a 3.3 (1-5 scale). The rating of 4 for the utility of generating student-centered learning objective indicates that students found creating their own objectives for the class more helpful than knowing those of the instructors. All students reported that the MT evaluation improved the success of the class for them. The average rating was a 3.75, indicating that although helpful, the impact of the MT evaluation was limited in extent.

IV. Cognitively-based Video and Audio tape Analysis

While the evaluations and the objective lists give the instructors' and students' points of view on the classroom, analysis of the classroom process is intended to give a more detached and objective perspective. Towards this end, the dialogue was coded for exchanges, content coverage, and cognitive activity.

A. Interaction

There was little variation between the proportion of dyad interactions between the class early in the semester and the class later in the semester (see Tables 3 and 4). The first class showed dyadic propositions to occur slightly more than group-directed propositions (53%). This class's first session contained more group-directed propositions (53%) while dyadic interactions predominated in the second session (57%). The second class of the semester followed a similar pattern. The first session contained more group-directed discourse (58%) while the second session was relatively balanced (51%). The total interactions for the second class of the term favored group-directed propositions only slightly (51%). Tables 3 and 4 are summaries of these interactions.

Tutor interactions that were group-directed increased from 61% to 71% of total tutor interactions during the second sessions. This may reflect the tutor's regulation of discussions about the domain content and the application of new knowledge to the case.

	Tutor	S1	S2	S3	S4	S5	S6	Group	Total statements initiated
Tutor		1	3	2	13	4	3	47	73
S1*f*	4		12	12	16	4	3	40	91
S2	9	7		6	6	10	6	43	87
S3	9	10	8		21	6	1	42	97
S4	16	9	8	12	1	12	5	71	134
S5	5	8	14	5	16		7	27	86
S6	9	4	5	3	10	6		33	70
Group		1	1						2
Total statements received	52	40	51	40	83	42	25	305	

Table 3. Interaction summary for the first class (1.23.96 and 1.30.96). Individuals on the Y-axis initiated exchanges with individuals on the X-axis. Sub-totals calculated for both initiated statements (Y-axis) and received statements (X-axis).
***f* denotes student facilitator.**

In contrast, student interactions (54% to 44%) and facilitator interactions (56% to 46%) both decreased between the first and second sessions.

B. Content Coverage

The first class involved cases dealing with weakness (1.23 to 1.30 class) and the second the structure and function of the visual system (4.2 to 4.9 class). During the course of the two classes (a total in-class time of four hours fifteen minutes), students discussed 65 Neurobiological topics. Thus, on average the students discussed a new topic every four minutes. However the sessions varied in the topics discussed based on the actual activity that the students were performing. First sessions typically focused on hypothesis and learning issue generation and, therefore, were not information-intensive. Second sessions

	Tutor	S1	S2	S3	S4	S5	S6	Group	Total statements initiated
Tutor		3	10	8	3	4	9	82	119
S1*f*	11		10	14	7	3	5	54	104
S2	13	8		17	20	8	4	67	137
S3	20	4	16		22	8		82	158
S4	26	7	16	23		18	6	68	161
S5	10	7	6	10	12	1	3	53	105
S6	17	4	3	10	2	9	6	35	80
Group	2								2
Total statements received	98	33	61	82	66	51	33	441	

Table 4. Interaction summary for the second class (4.2.96 and 4.9.96). Individuals on the Y-axis initiated exchanges with individuals on the X-axis. Sub-totals calculated for both initiated statements (Y-axis) and received statements (X-axis). *f* denotes student facilitator.

tended to focus on content coverage by the students. However, this content coverage only accounted for that which was discussed in class. It excludes content that the students covered outside of class and did not discuss as a group. In the "weakness" sessions, students covered 18 topics relating to the following NBME informational learning objectives as they appear listed under the content items covered by the USMLE step I (1996):

- the functions of neurons, synapses, and regulatory processes
- signal transduction

Some examples of the pertinent topics covered are:

- the role of the Na/K ATPase in establishing and maintaining resting membrane potential
- the effect of monovalent cations (K, Na, Cl) on membrane potential
- action potential v. EPSP v. IPSP
- the Goldman equation
- the function of the voltage-gated channel in action potentials

The class also discussed five topics that were not directly related to the above NBME content items, but rather were related to other physiologic or clinical concepts, most of which are mentioned as content items elsewhere in the NBME list. Some examples are:

- the effect of hypernatremia on cell excitability
- the physiology of hydrochlorothiazide
- the role of bone metabolism in regulating serum calcium levels

The second class dealt with the NBME content items:

- vision
- control of eye movements

This class covered 25 topics relating to these content items, such as:

- the visual pathway from the retina to occipital cortex

• abstraction of contrasts leading to perception of edges by the visual system at the levels of the retina, lateral geniculate, area 17 simple, area 17 complex, association cortex

• role of pretectum in pupillary reflex

The class discussed seventeen other topics in the two sessions on vision. They included:

• pre-central and post-central gyrus function and their organization of sensory areas

• the definition and diagnosis of stereognosis

• the electrophysiology of the EEG

As referred to in the Methods section, content coverage was coded only for those topics that were discussed in the group, ended with a resolution of a concept, and contained correct information in the resolution. The interaction summaries above show the heavy traffic of interactions in the classroom. A direct product of this traffic is a plethora of questions regarding both basic science and clinical medicine. Only a subset of all questions raised by the group were answered according to these coding criteria, potentially giving the students the impression that they cover little content. Rather than the actual quantity of content covered, the sense of poor content coverage may be due in part to a relative excess of questions raised compared to number of questions answered by the group.

C. Activity

Fifteen major activities were most apparent in the SGP classes when they were narratively coded. These activities were derived in part from studies of reciprocal teaching (Brown & Palinscar, 1989). However, most were derived *de novo* from the classroom interaction. Reading the problem, generating hypotheses, clarifying learning issues, and planning the session are all activities with similar to those identified by Brown & Palinscar. However, these are more specific to the problem-based learning environment of Small Group Process.

Temporal coding permitted summarizing the activities according to the time spent on each in the classes. The Figure 1 is a summary of the time spent on seven of the most prevalent activities that the students practiced in SGP.

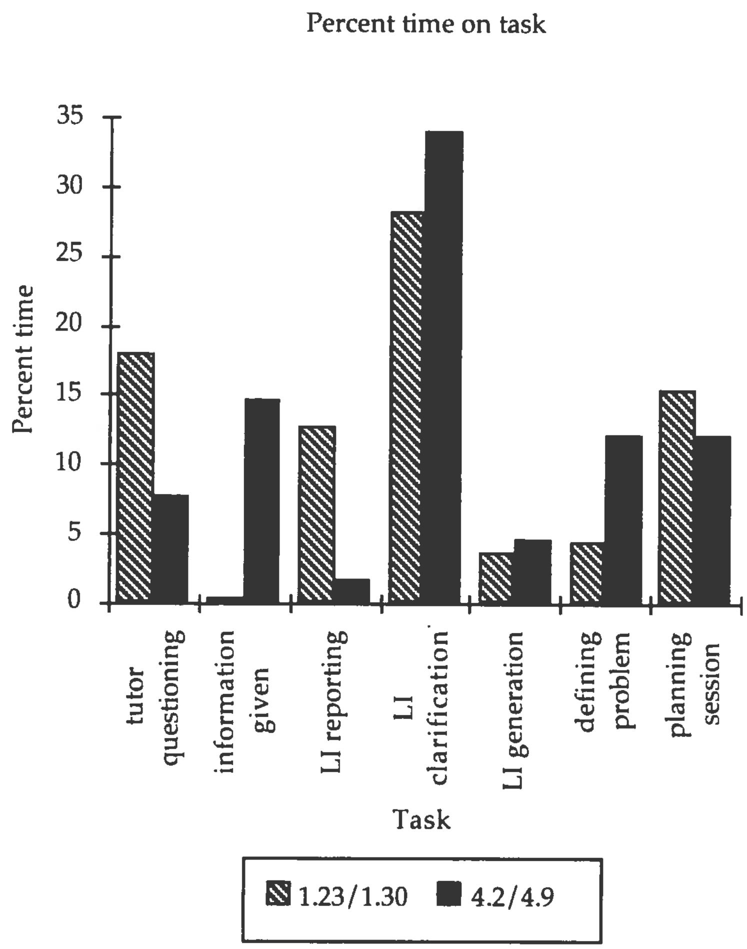

Figure 1. Graph comparing the percentage of total time in two classes (each composed of first and second sessions) spent performing cognitive activities. Seven of a total 15 coded activities shown based upon total percentage time performed in SGP. Sum of other eight activities not shown: 17.2% for 1.23/1.30 class; 12.6% for 4.2/4.9 class. LI, learning issue.

The majority of time spent in SGP is clarifying the problem data, hypotheses, and learning issues. The activity comprised 36% of the total interaction time in the 1.23/1.30 class and 47% of the total interaction time in the 4.2/49 class. One activity in particular, "planning session" is often-times referred to as "process" by the students. This activity involves the business aspects of managing the class process by the students. Since this cognitive activity is not directly involved with acquisition of domain knowledge, it is often a point of frustration for the group. Indeed, it may very well frustrate the efficiency of the classroom that the students rated as "fair to poor" (2.7/5) on the MT and ET evaluations. However, this set of management activities only takes up 15.4% of the first class studied in the term and 12.2% of the second class.

1. First Sessions - defining the problem and setting learning goals

Figure 2 shows the percent time spent on the fifteen coded activities in the classroom for the first sessions. Activities are in keeping with the expectations of the first session: reading and clarifying the problem; generating hypotheses and learning issues; and clarifying hypotheses and learning issues. Together, these activities accounted for approximately 60% of the in-class time. Several features are notable between the first sessions of the two classes studied. Tutor verification of the student discussion and tutor modeling of reasoning processes is present in the first class only. This may be due to scaffolding of the classroom practices early in the semester by the instructor to support and guide student inquiry. As the semester continues, the instructor support may then, consciously or unconsciously, fade away as the students gain more facility with SGP. As the students become more self-directed and aware of the group's progress, the instructor may intervene less. In addition, students in the second class spent nearly five times the percentage of class time clarifying the problem as the students in the first class. This may be a function of problem difficulty and increasing complexity of language in the problem over the course of the semester. That the students in the second class also spent nearly five times as much time reading the problem as did those in the first class supports this hypothesis.

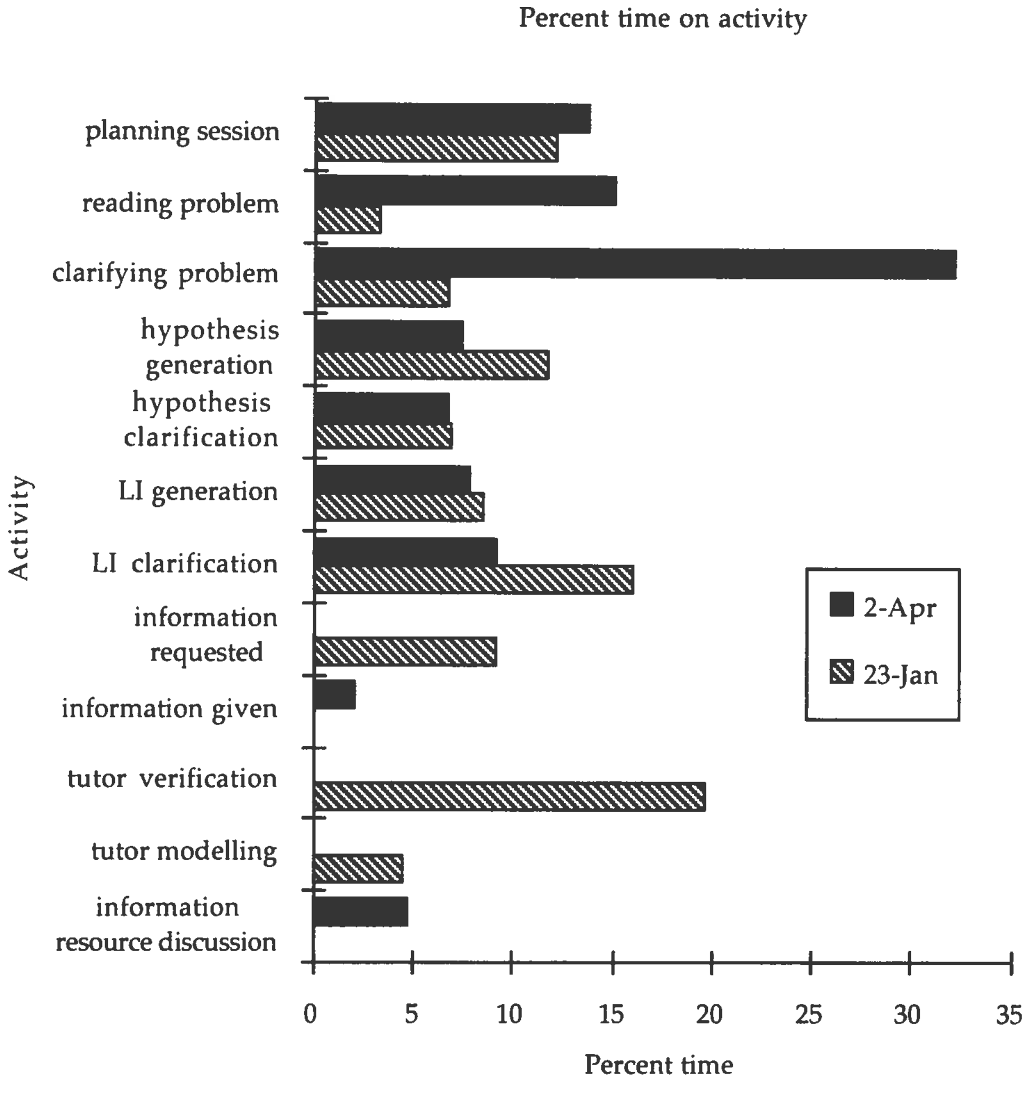

Figure 2. Graph showing the percent time spent on cognitive activities in first sessions. Zero categories not included in graph: LI review, LI reporting, summarizing.

The greatest variability among activities was in problem clarification (6.9%, 32.2%). This maybe due to several changes in the course over the semester. Problem complexity may increase as the cases incorporate more clinically-oriented domain content. For example, while the case of the first class was grounded in "weakness" and the subject content that the students were to cover involved ions, the second class studied involved a relatively complex case dealing with vision where multiple clinical terms (homonymous hemianopsia, photophobia, extinction) were used in the problem statement. Clarification of such terms would be essential to setting learning issues and understanding the case presentation. Another factor contributing to this change may be the change in course structure that occurred between the first and second classes. The first class's first session was one hour long while the second class's first session was only half an hour long. Yet, although the percentage times differ by nearly 5-fold, the actual time spent in the activity only differed by a factor of two (3.3 minutes, 7.2 minutes).

In addition to increasing clinical complexity, the students also may become more inclined to ask further questions that better clarify the clinical presentation or seek new information that may be relevant to the problem but not included in the problem statement. In the following excerpt, the students search for new information on a patient presenting with visual symptoms (4.2.96 session). The students are searching for other variables (medications, age) that may contribute to qualifying any underlying factors that may be contributing to disease. :

Tutor: She's 30, she didn't eat anything special. she's not having trouble speaking. And she uses the medication for the five days before her period.

S1: Ooh. every period.

S2: Is this--

S3: And for how many years has she been--

S4: Oh is she having her period now?

S2: Yeah that's ... is she on the medication right now?

The tutor provides the students with additional problem information in response to student questions regarding patient's age, diet, ability to speak in the emergency room, and regular medications. The students then proceed to assess the potential relevance of new datum to patient's symptoms. In the continuing excerpt, the students contextualize the new data with respect to other data that the group has gathered on the patient's background:

> Tutor: Yeah, she just finished her period.
>
> S5: She just finished it.
>
> S4: She just took the medication.
>
> S1: Five days before the start of her period.
>
> S4: She took the medication, Like, eight days ago?
>
> S3: For the last seven years...
>
> Tutor: She's just finished. She starts 5 days before her period and takes it during her period. Between five and eight days, depending on how much she's cramping and swelling.
>
> S3: For how many years?
>
> Tutor: I don't know. The last couple years.
>
> S6: Well, maybe it's a combination.
>
> S1: Well, yeah. So no I think that we need another variable.

Kassirer and Kopelman (1991) speak of expert clinicians using characteristics, such as patient demographics and past medical history in guiding hypothesis generation and refinement. Perhaps the students, in gaining facility and experience with applying basic science to clinical problems, exercise this heuristic more frequently as the semester progresses. Although their knowledge base is still that of a novice, perhaps the group tries out certain heuristics in the form of asking further questions about the problem.

Clarification of hypotheses and learning issues are less variable between the two classes than problem clarification. These are both activities in which the group tries to come to a mutual understanding of an individual's proposition. In the following excerpt the group is trying to clarify the basic science mechanism behind a student's (S1) hypothesis of how a medication maybe be causing a patient's weakness (1.23.96):

> S1: Well, I'll try my one that I said before which is that she took this medication, it's affecting her Na/K balance. The nerves that supply skeletal muscle use Na and K to somehow regulate the storage of acetylcholine. And therefore, somehow having those things down regulated means that she is somehow unable to store enough of that neurotransmitter to successfully move her muscles. And that --
>
> S2: Because of acetylcholine release.

S1 uses a chain of basic science causal mechanisms in an attempt to explain the patient's symptoms. S2 clarifies this causal string by verifying that acetylcholine is what S1 is referring to by that phrase "that neurotransmitter". This stimulates another hypothesis and basic science explanation:

> S1: Well, because she, I don't know. Because somehow she doesn't have enough of the neurotransmitter which she doesn't have enough of because of the cation. The rest of her body doesn't use cations to affect neurotransmitter storage or release and therefore it isn't affected. [in response to S2's statement, S1 continues to explain the how the mechanism might only affect skeletal muscle and not other systems in the body.]
>
> S3: Except calcium affects the release of -- I think for sure -- of neurotransmitter.

S2 and S3 are both clarifying S1's attempt at giving a causal explanation to the patient's symptom of generalized muscle weakness. While S2 is confirmatory, whether the neurotransmitter spoken of is acetylcholine, S3's clarifying comment is more of a challenge. By positing that acetylcholine release in all neurons is dependent upon calcium, S3 is bringing S1's causal chain into question by using another basic science concept. The group continues:

S2: But he's talking about storage so it would be different. [clarification of S1's causal mechanism by S2 in light of new information] And I'm thinking that it has something to do with neural conduction. You know, at the motor neuron...specifically at the skeletal motor neurons. Like for some reason action potentials either aren't being generated or are being lost in the process and therefore she is unable to have motor movement. [new causal mechanism is suggested for patient's symptoms, referring to differences between action potential conduction rather than acetylcholine storage in nervous versus skeletal muscle] And I guess that involves the Na and K, you know, like levels, but for some reason the motor neurons are especially sensitive whereas the other ones are not? [asks for further clarification by the group's knowledge of motor neurons and action potential conduction at the neuromuscular junction.] I don't know. [indicating to the group that S2's level of understanding of the mechanism suggested is incomplete]

S4: Maybe the threshold is different.

S1: That's a good one.

S5: So S1 is the reason that you brought acetylcholine into it is because that's one thing that distinguishes between skeletal and non-skeletal? [further clarification of S1's hypothesis]

S1: No, I don't know. But [the tutor's] used it so I used it. No, I don't know yet. I mean that's one of the things that we should find out.

S1 recognizes the limits of his own knowledge regarding hypothesis. He suggests a topic for further study by the group regarding how the basic science concepts of acetylcholine functioning in skeletal muscle versus nervous tissue relate to generalized weakness. This stimulates more clarification of the hypotheses regarding the patient's weakness:

S2: Well, acetylcholine is the neurotransmitter at the neuromuscular junction.

S5: But I'm just asking is there a reason to think that it is at the neurotransmitter level as opposed to the resting membrane hyperpolarization level or maybe both, I mean... I was wondering why he decided on the acetylcholine ... to bring in the neurotransmitter. [questioning the relation of S1's and S2's mechanism and the possibility of them both contributing to the patient's problem] It wasn't self-evident to me. [commenting on own awareness of what concept(s) the group is trying to understand]

S1: Oh, well the reason I did that is because like I thought about trying the one that S2 proposed, but I couldn't think of a reason why motor neurons would be affected while sensory neurons weren't. So I thought, well, why don't we see if it's affecting... since we do know there is a difference between motor neurons and sensory neurons with respect to which neurotransmitter they use, maybe that's the connection. [responds to S5 by explicating own thinking leading to the hypothesis about acetylcholine]

S5: OK.

S1: It doesn't seem likely to me. [commenting on how much sense the hypothesis makes with respect to own knowledge base]

The process of clarification shown above is a form of "explanation-based learning" that Groen and Patel (1991) call for in PBL. As the students work through hypotheses, they must explain their conceptualizations to one another. This group-oriented dialogue is essential to establishing a consensual list of learning issues. In the process, the students are actively mulling over the basic science concepts that they bring into the discussion. However, contrary to novices and intermediates, experts do not overtly apply biomedical knowledge to clinical reasoning tasks (Boshuizen & Schmidt, 1992). Will the students perform similar activities as experts? Arguments have been made that much of clinical thinking may not rely on biomedical knowledge (Patel & Kaufman, 1995; Patel et al., 1989). However, that expertise uses little biomedical knowledge explicitly does not rule out the development of expertise from a certain body of biomedical knowledge. The model of knowledge encapsulation (Boshuizen & Schmidt, 1992) requires that biomedical knowledge be hierarchically organized into patterns that facilitate rapid and accurate problem-solving. The students in the above excerpt are actively contemplating the relation of basic science concepts to clinical realities and to other basic science concepts. This application of knowledge fits with the active processing required for organizing new knowledge into meaningful networks (Boshuizen & Schmidt, 1995; Whitehead, 1929).

In addition, the discussion of these concepts is not directly related to the clinical presentation, but rather occurs one step removed from the clinical problem. The students are building a common understanding of how basic science causality (e.g. membrane potentials, neurotransmitter levels, ion concentrations) can produce a physical symptom (weakness). The question is not, What is the patient's diagnosis? but rather How can we explain the symptoms and signs using basic science concepts? This might avert the potential problems of de-contextualization of basic science information as observed in other problem-based learning classrooms (Patel et al., 1993; Patel et al., 1991). No matter what the teaching method, it seems that this process of backward reasoning will continue until the student's knowledge base is sufficiently large and integrated to permit forward reasoning. This directionality of reasoning is, thus, more a function of the character of one's knowledge than a character of the teaching method.

The tutor's role in the first sessions of the two classes is quite different. In the first class, the tutor is active in two ways: (1) questioning the student's understanding of topics of discussion and (2) modeling the cognitive processes that he would like the to pursue through SGP. This is not present in the second class later in the semester. The following is an example of the modeling process in which the tutor is briefly describing how he would approach refining hypotheses about a patient's weakness:

> Tutor: One way of doing that would be to ... and this isn't to introduce a new direction... but now that you've done this is to walk back through it and make sure that it adds up. [suggests a mental procedure for the group to practice in assessing the relative significance and importance of their hypotheses with respect to the data provided by the case] It was helpful to know, as you pointed out, that the subject is membrane potentials. But it's still, you know good to do it. So given the hypotheses that you have here, which ones can you literally, you know, are probably not going to be that relevant and which ones are more a priority? [suggests a question with which to rank order hypotheses based on the data provided - note similarity between the tutor's suggested cognitive activity and the hypothetico-deductive reasoning] Remember for a kind of count at this point it's kind of good to think,

"OK, if I was doing my little final exam on this one, how would I link my hypothesis and the problem? What physiologic mechanisms would let me link that?" [models his own thinking process as if he were a student in his own teaching method's assessment] So for example, say, you know, the toxin did it. And I happen to know that alpha-bungarotoxin blocks acetylcholine receptors and if you block acetylcholine receptors a person gets weak and so probably a Formosan krait crawled into her bed at night and bit her. Was she in Formosa?

Perhaps this is a form of cognitive apprenticeship (Collins, Brown, & Newman, 1989) in which the tutor begins by modeling thinking for the students, progressing later to coaching thinking and finally to fading as the students gain facility with in SGP.

In all of these cognitive activities the students are addressing the major AAMC criteria (1984) for UME: communicating effectively; applying knowledge to clinical problems; finding, using, and interpreting information resources; and learning in a self-directed manner. Along the lines of Ram et al.'s (1995) model of goal-driven inquiry, the students are learning actively by performing a reasoning task (understanding the presentation of a clinical case), setting and postponing unsatisfiable learning goals, and reflecting on their own performance. However, the process tends not to meet the criterion of "diverse": using multiple strategies to acquire , construct, and re-organize knowledge (Ram et al., 1995). The student's inquiry process is structured around the hypothetico-deductive model of clinical reasoning. Thus, the students must structure their discussions around the specific activities of generating hypotheses and weighing those hypotheses with new problem data. As a result, the structure of their process of inquiry tends to be uniform; however, the skills that they apply within that structure are diverse (e.g. communicating, clarifying, consensus-building, drawing representations of concepts).

2. Second sessions -- bringing new knowledge to the classroom

The second sessions of both the class early in the term and the class later in the term show significant similarities in the distribution of time to activities. In particular, both classes spent over 35% of their class time clarifying learning issues. While there was an

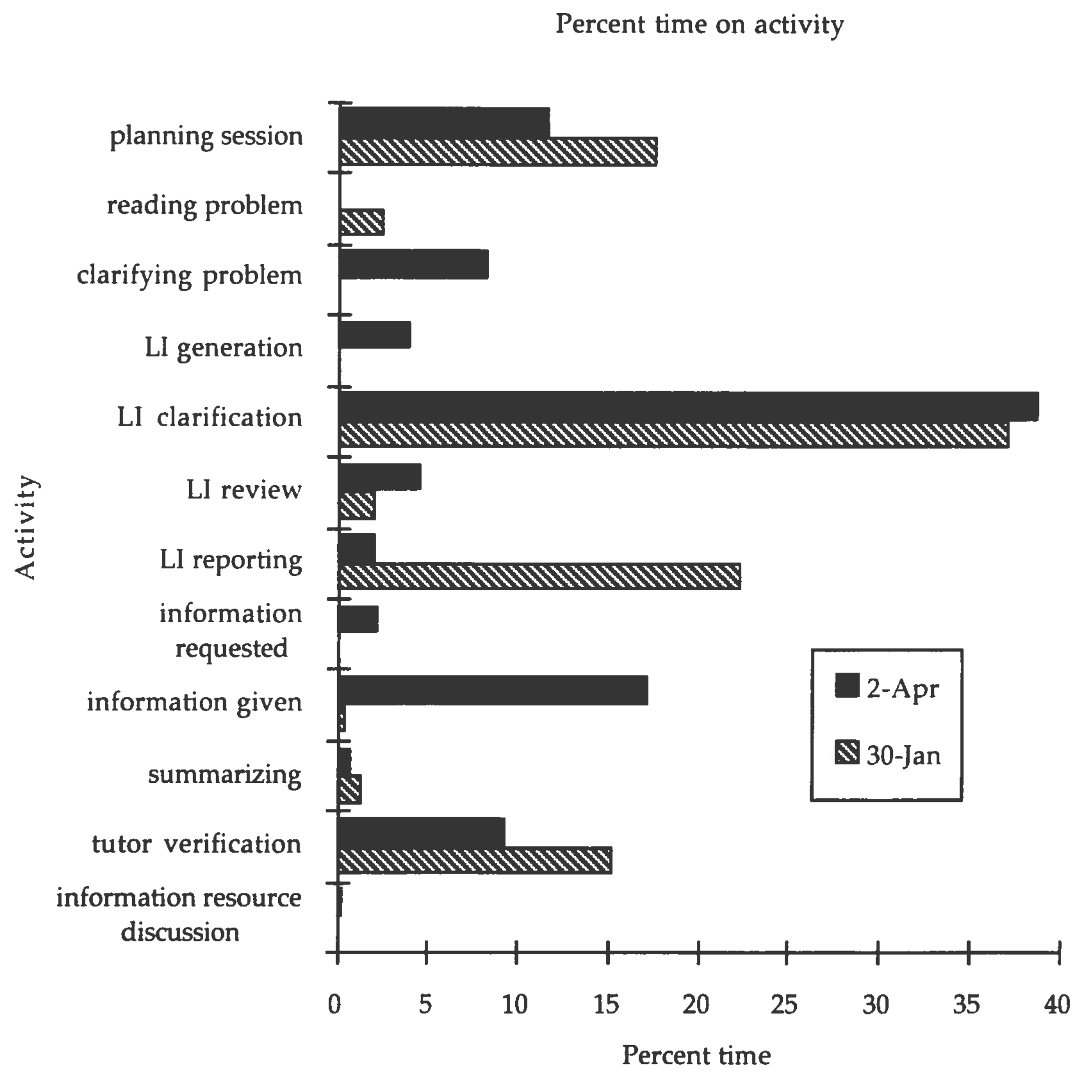

Figure 3. Graph showing the percent time spent on cognitive activities in second sessions. Zero categories not included in graph: hypothesis generation, hypothesis clarification, tutor modeling.

emphasis of the first class on the reporting of learning issues (22.4%), the second class tended to spend less time on reporting (2.1%) and more time on clarifying the problem further and giving information that was not specifically covered by the learning issues.

As might be expected, there was a noticeable shift towards clarifying learning issues (37.2%, 38.9%) to the clinical case in the second sessions. However, there was a large difference between the first and second classes of the term in the levels of reporting learning issues in a didactic format (22.4%, 2.1%) as well as applying new knowledge to the clinical case (0%, 8.3%).

a. Learning issue reporting and clarification

The discussion of learning issues in both classes tended to occur outside of the context of the clinical cases that raised them. This was in part due to the explicitly stated intent of the instructors that the cases stimulate primarily content coverage rather than clinical problem-solving. This raises the question: will the discussion of basic science learning issues separate from the problem improve the de-contextualization of that knowledge? In the following dialogue, the students are working on a diagram of the organization of the visual system in the visual cortex (4.23.96):

> S1: And then... so we have orientation columns that go down like this... that respond to different orientations.
>
> S3: It says that each column contains a complete set of orientation columns, so that's what I don't understand. If this is a column and each one is supposed to...
>
> S1: Oh, no, each hypercolumn.
>
> S3: Oh and this is a hypercolumn? Oh...
>
> S1: And a hypercolumn is column that responds to a particular visual image, is that right?

Drawing the diagram of the visual cortex on the board, S1 shows the organization of the visual cortex. S3 questions her own interpretation of the model and stimulates discussion of the hypercolumn. S1 states her own understanding of the hypercolumn concept with the group's understanding and asks for the group's validation of her understanding. The students answer her question and proceed to connect their model of the visual cortex to the retina:

> S4: Not to a visual image, but I think to a portion of the retina.
>
> S3: I think it's enough columns so that all of the 360º are...
>
> S1: OK.
>
> S4: It says, "Each hypercolumn analyses a discrete region of the visual field." [using a source text to answer S1's questions about hypercolumns]
>
> S1: That makes sense.
>
> S4: So which has got to correspond to a portion of the retina. [relating the concept of hypercolumns to the organization of the retina]
>
> S3: OK.
>
> S2: That's really interesting.
>
> S1: OK, and so in that we have to have all the orientations represented. And then we also have to have represented from the ipsilateral eye and the contralateral eye. [evaluation of diagram's completeness with respect to hypercolumn concept and it's relation to retinal organization]
>
> S3: God, I get it! [confirmation of understanding]

The visual system is the "most complex of all sensory systems in the cortex" (Kandel, Schwartz, & Jessell, 1991). As the students work through the organization of hypercolumns, they are referring to an abstract representation, namely a text diagram. While the previous clarification excerpt dealt heavily with physiologic concepts (calcium and acetylcholine in the neuromuscular junction, the Na/K pump, membrane potential), this exchange is centered around a model of the visual cortex. However the cognitive activity is the same: the students are sharing their understandings to build a common concept. Since the discussion is centered on understanding the organization and meaning of this abstracted representation and not the model in specific regard to the clinical symptoms of the patient, perhaps knowledge acquisition is occurring in a de-contextualized format. Once again the question the students are grappling with is, How does the basic science explain the symptoms?

The activity of reporting learning issues found in the first class of the term (14.4 minutes) is not present in the second class of the term. Interestingly, the students appear to transition from reporting to clarifying their learning issues interactively (from 23.9 minutes to 43.8 minutes). Since the sums of these activities in the two classes is approximately the same (38.3 minutes, 43.8 minutes), it seems that the time covering new content is about the equal while the strategies that the students use differ. Two reasons may account for this change. First, this may be a sign of improved facility with interactive concept building. Perhaps through the repeated use of the cognitive skills required by SGP (e.g. the student and instructor-generated learning objectives for the class), the students are better able to learn cooperatively. The statistically significant improvement in the students' evaluations of how well the class met the instructor's cognitive skill objectives and many of the student objective seems to support this hypothesis. Second, this transition may be a function of the complexity of the learning issues and the domain. Given the relative difficulty of the content that the students had to cover in the second class, perhaps they were more dependent on the group for clarification of difficult concepts. The discussion of the text diagram in the excerpt above supports this idea.

Despite the decrease in didactic presentation of new knowledge, the actual number of topics covered by the students in the second class of the term increased. While the second class covered forty-two content topics interactively, the first class only covered 23 in their semi-didactic format. This may evidence Ram et al.'s (1995) criterion of diversity that was referred to above. Within the fixed framework of hypothetico-deductive inquiry, the students seem to use different strategies for covering content within the time-limits of the class. In this sense, the structure of the class seems to serve as a problem itself, stimulating students to set goals directed at the question: how can we cover the relevant domain knowledge best given the time that we have?

The learning objectives set by both instructors and students address the issue of the purpose of class time. Both objective sets encourage goal-setting and self-evaluation of progress. However, the student's goal of making class time efficient may support the use of multiple strategies for content coverage within class time. In contrast, the instructors picture class time more as serving to "increase the perceived informational needs in a given area of Neurobiology" (3.5/5 MT; 4.1/5 ET). The actual content coverage is meant to take place outside of class as "use of self-directed study and information resources" (3.7 MT; 3.7 ET). Thus, the progression towards a more interactive classroom process may reflect an acceptance by the students of the instructor's goals.

b. Clarifying the problem

Clarifying the problem in the second sessions involved students actively trying to solve the clinical case. Although their discussions of basic science concepts occurred both within and outside of the context of the clinical case, the actual coded process of clarifying the problem in the second session required that students integrate the physical findings and symptoms into a whole picture. An example of problem clarification follows. In this discussion, the students are contemplating how the patient's visual symptoms fit in with other physical symptoms:

S1: So I guess if it had to do with the optic radiation a lesion, then that affected the parietal area would include the optic radiation?

S2: Yeah. The optic radiations go from right behind the chiasm to almost back to the occipital lobe.

S1: So she could have some sort of lesion in the radiation and the parietal lobe? Is that possible?

S2: I mean she could have a lesion...right, exactly, good. Like something that's here in the parietal lobe that affecting optic radiation from the right eye, the right optic tract.

S1 contributes a basic neuroanatomic fact to confirm the hypothesis that a lesion of the optic radiation might be causing the patient's visual symptoms. S1 draws from this fact by hypothesizing a clinical condition that might cause dysfunction in the visual system. Another student challenges S2's clinical hypothesis of a lesion in the parietal lobe by stating a basic science fact regarding sensation in the brain:

S3: So why's she getting headaches if there is no lesion there and there's no sensory in the brain itself?

Tutor: How do you get headaches?

S1: Didn't we hear today that they come from swelling and a certain amount of an inflammatory response so that if she has some sort of lesion or tumor or growth she might be having some sort of inflammation? or it might be pushing on other parts of the brain? [hypothesis]

S4: You get feeling from the dura mater.[fact offered in support of the inflammation hypothesis]

S3: The dura mater right? So that could be an aneurysm? [another hypothesis offered in response to new fact]

S1: Oh yeah, she might have an aneurysm.

This activity was the only time in which the students seemed to focus their discussion to the case specifically rather than basic science issues which related to the case. Furthermore, this activity only occurred in the second class studied. If learning is defined as understanding how to use knowledge in context (Whitehead, 1929), then this activity is essential to the learning process. For example, the placement of the optic radiations within the parietal lobe is an inert neuroanatomic concept until applied to the case: "*S1: So I guess if it had to do with the optic radiation ...a lesion, then, that affected the parietal area would include the optic radiation? / S2: Yeah. The optic radiations go from right behind the chiasm to almost back to the occipital lobe.* " However, previously mentioned studies comparing PBL curricula to conventional curricula warn that such contextualization excessively limits the universality of the concept learned, inhibiting transfer to other clinical contexts (Patel et al. 1993; Patel et al. 1991). So, is this process valuable? VanLehn (1996) argues that only through repeated application of concepts to problems does the learner sort superficial problem features from structural problem features, permitting the appropriate generalization of principles from the problem's solution. When the student should begin to form connections between the basic and clinical sciences does not have an answer. In the context of the class, only 8.3% of the second session's time was devoted to solving the clinical case. This activity may serve as another form of cognitive apprenticeship in which the tutor scaffolds clinical thinking instead of SGP thinking. Seen in this light, stimulating the clinical use of new knowledge after the students have acquired a limited fund of knowledge may outweigh the potential for de-contextualization problems.

While the sessions vary in many cognitive activities, both first and second sessions show similarities in the proportion of time devoted to planning and managing the session. This ranges between 11.8 to 17.6%. This narrow range relative to other activities suggests that time spent structuring SGP by goal-setting and checking progress towards goals remains relatively constant across problems.

3. Planning sessions

One feature of the group-directed learning is regulation and self-awareness. The interactions of a group can be thought of as an explicit version of various roles that one uses in individual cognition (Brown & Palinscar, 1989). If self-awareness of learning is a part of any goal-driven inquiry process (Ram et al., 1995), then it should be found consistently in both individual and group-centered learning. Session planning activity was relatively constant across the first (12.3%, 13.8%) and second sessions (17.6%, 11.8%) of both classes studied.

Planning sessions is usually an activity focused on the student facilitator of the group whose job is to ensure that the group's goals are being followed and that everyone has a chance to contribute to the session. The facilitator's role is to structure the classroom and, hence, the learning process. All of the actions of the facilitator are directed according to the group's wishes. No one person is ever really in charge. A facilitator must evoke responses from the group in a timely, directed fashion that permits him or her to set goals for the group:

FACILITATOR: Does anybody want to write the learning issues on the board or do we have them, um ...

S2: They should be on there.

S3: It's these over here... the learning issues deferred.

group: uh-oh.

S4: I'll write them.

FACILITATOR: And we have until 4 for this. How much time do we want for splitting up learning issues?

S5: Oh, that's right.

S3: We should take into account that we don't just divide up learning issues, we end up re-forming learning issues.

FACILITATOR: Is fifteen minutes enough? Is that pushing it?

S6: I'll alert us at 3:45.

Once specific goals have been set for the session, the facilitator walks a fine line between being a participant in the group and a regulator of it:

S1: We talked about one and two, are we going to abandon this and go to cortical mapping in area 17.

S2: Well, to me one is... we have not done cortical processing. We have done subcortical processing.

S1: Right.

S3: I agree.

Based on the skills set by the students and instructors, the facilitator is responsible for a large number of cognitive functions in SGP: meeting work goals, managing time efficiently, following the group's goals, setting learning goals and evaluating progress towards those goals, and building consensus. Within the context of the group, then, being facilitator compounds one's cognitive workload with a metacognitive role. Whether this additional role frustrates the acquisition of domain knowledge is unknown. Taken in the context of the AAMC (1984) and the Pew (1995) recommendations for skill acquisition in UME, the role of facilitator maps to communicating effectively with patients and their families. While one may not use SGP explicitly in dealing with patients, some skills such as consensus building and following group goals might be of value.

Small Group Process is a PBL teaching method that appears to encourage cooperative explanation of basic science concepts in terms of their clinical manifestations.

Students spent one-third to one-half of their time in this teaching method actively engaged in building a common understanding of the basic sciences at hand. Given the limited amount of time that students have in class, however, the practice of cognitive skills in pursuing group learning goals may compromise some of the breadth of informational learning relative to conventional curricula. Students cover the content of the domain (i.e. neurobiology) in a non-linear fashion. Yet they discuss a surprisingly large number of basic science and clinical ideas. Many of these discussions are stimulated by a clinical case but seem to focus on understanding the basic science concept itself more than arriving at a specific diagnosis through backwards reasoning.

Chapter Four: Conclusion:

The purpose of this study was: (1) to identify and describe the cognitive skills that Small Group Process encourages students to practice; and (2) to relate these skills to the goal of medical education -- the expert clinician. Both quantitative and qualitative data were collected from course evaluations, student surveys, and through the observation of classroom activities and discourse. The following discussion reviews the findings from these data in light of the current literature on medical education and expertise.

I. Creating and Evaluating Cognitive Skill Objectives

The cognitive skill objectives of Small Group Process include many of the features of goal-driven inquiry, allowing for self-aware, self-directed learning (Ram et al., 1995). A major objective of undergraduate medical education is making the student a life-long learner (AAMC, 1984). The ever-changing practice of medicine requires not only that a student be able to pursue knowledge actively in becoming an expert, but also that s/he be able to update that knowledge base in continuing practice. Both student and instructor perceive the SGP classroom as encouraging the practice of skills essential to independent learning and self-awareness. The skills identified by students and instructors (e.g. setting work goals, identifying unclear concepts, and using interactions to increase perceived needs in a domain) all are, arguably, constant across the novice-to-expert continuum. These skills pertain more to learning processes and social interactions rather than to the actual cognitive processes as exemplified by an expert. Thus, SGP encourages skills that ground the pursuit and maintenance of expertise rather than stimulating the novice to perform like an expert in the classroom.

The acquisition of expert problem-solving ability may involve specific stages of knowledge encapsulation sought through experience as conceived of by Boshuizen and Schmidt (1992). Others have proposed that the development of expertise is less stage-specific and more dependent on learning specific clinical relationships that may be cognitively distinct from basic science knowledge (Patel and Kaufman, 1995). Whatever the case, the objectives for SGP target particular skills that do not specifically involve the practice of expert thought processes. The students do not learn forward reasoning nor do they acquire a level of integration in their knowledge bases to make them experts in anything. They do not encourage the practice of heuristics that have been shown to be cognitively disadvantageous to learning in medicine (Elstein, 1978). Instead they encourage the practice of skills that seem to serve similar functions in both experts and novices. These skills are widely recognized to be essential to expert clinical practice (Finnochio et al., 1995; AAMC, 1984).

Although these objectives are similar between students and instructors, they are not identical. Instructor objectives tended to relate to abstract cognitive functions such as contextualizing knowledge and simplifying complex concepts. The instructors' intentions reflect an intention of stimulating active inquiry. While these intentions may favor the application and use of knowledge, those of the students seemed to reference the need to explore large volumes of information efficiently through the classroom process. Instructor objectives do not directly refer to this objective of handling large volumes of information and managing time efficiently. Overt discussion of the expectations of both students and instructors may avoid miscommunication and misapplication of learning strategies (Bruner, 1984). The improvements in evaluations of the instructors' skill objectives over the term may be indicative of an alignment of student and instructor intentions in learning.

Since backwards reasoning drives novice inquiry, students spend a large amount of time weighing their hypotheses against the problem data. This process is slow and takes time away from learning content knowledge. This potentially frustrates the students' intentions of making SGP help them to handle large volumes of information within the domain. The student evaluations of this objective (mean = 2.75, SD = 0.91) seem to support this hypothesis. However, the reasoning process may also contribute to effective causal reasoning as observed in an excerpt from one of the transcripts.

Students in SGP must divide their time between knowledge and skill acquisition. As the extensive list of cognitive skill objectives shows, student have a significant responsibility for skill acquisition. Thus, to neglect this learning in evaluating the course's effectiveness would fail to give a true reflection of whether the course was fulfilling all of its objectives. Evaluations of any program should be specific to the program's goals (Berk & Rossi, 1990). Thus, evaluation in SGP should refer to skill acquisition and practice as well as content coverage. All of the students reported that evaluating the course based on explicit cognitive objectives was helpful. Interestingly, students found that identifying their own cognitive skill objectives was more helpful than knowing those of the instructors. This latter finding emphasizes the importance of understanding student intentions for learning in a given teaching method.

II. Learning Styles and Evaluations

Preferences in learning also seem to affect perceptions of the quality of learning in SGP. Students who perceive themselves as having characteristics that SGP attempts to encourage (i.e. active learning, interactive concept-building, intuitive thinking, re-evaluation of understanding) consistently rated the class as more successful in meeting the set objectives than students with alternate self-perceptions. Students practice what they know in class. This supports Bertini's hypothesis that cognitive congruence between instructor and students leads to greater congruity between student goals for learning (Bertini, 1986). Students familiar with the skills that the teaching method requires may be able to focus more of their attention to learning the domain knowledge. Students lacking such skills may be forced to divide their attention between learning domain knowledge and learning the skills required by the process.

Any correlations that we can make in this classroom are limited by two factors: the number of participants in the study (n=12) and the source of the data. Since the students switched classes at mid-semester (see Methods), more valid correlations require calculations that are specific to the groups in which the students worked. In this study, the evaluations and the learning style characteristics were taken as one data set. There may be statistical relationships that are masked by collapsing the two groups of six into one group of twelve. Furthermore, self-reported learning styles may not be a completely valid representation of how students actually learn. Experiences other than metacognitive reflection may impact preferences for learning. Previous negative experiences with SGP, interpersonal problems within the group, or the demands of external assessments such as the USMLE I may each affect the perceptions that a student has of his or her own learning style. Nevertheless, the relationships have some internal validity as reflections of the class composition. They are not externally valid, even when statistically significant. As is the theme of this entire study, these learning style correlations are meant to be descriptive, not confirmatory. In this classroom, certain characteristics of learning do relate to an improved perception of the overall effectiveness of the SGP teaching method.

III. Cognitively-based Video and Audio Tape Analysis

Education is more than simply defining a set of goals for learners to achieve. Defining a desired set of competencies is helpful in planning the route one takes in reaching expertise. However, one cannot replace the role of experience in learning. The role of education is to stimulate learners to pursue experience as well knowledge. While the Flexner report's model of the physician-scientist helped to standardize medical education in the US, it did not improve our understanding of the critical transitions involved in becoming an expert. Much of undergraduate medical education is directed at creating a broad, inert knowledge base. Problem-based learning encourages students to learn and test knowledge in the context of clinical problems.

Small Group Process is a variant of problem-based learning that uses clinical cases to stimulate cooperative discussion of related basic science concepts. As such, it differs from other PBL methods in that the focus of learning is on the explanation of knowledge rather than arriving at a diagnosis by learning new knowledge. Patel and Groen (1991) believe that "pondering the adequacy of one's explanations" is more important to learning than simply solving the problem at hand. One can thus conceive of three levels of learning: the first, inert knowledge acquisition; the second, use of that knowledge in real-world situations (Whitehead, 1929); and third, reflection on how appropriately one uses that knowledge. These are three major features of goal-driven inquiry (Ram et al., 1995). Models of clinical expertise might define this set of features as "life-long learning" (CMA CME Conference, 1995). However, such terms collapse the skills required for life long learning, leaving them implied but not stated. Life-long learning requires self-awareness, formulating questions to direct learning, and the ability to pursue answers to those questions.

Discussion in SGP stimulates self-awareness of knowledge. When addressing the group, students seem to qualify their contributions regarding the level of confidence and investment that the students have in their propositions. Clarification of hypotheses and learning issues involves active contemplation of understanding as the students challenge and question their own and the group's knowledge. If enhancement of learning basic science concepts is a goal of medical education, SGP appears to meet that goal (AAMC, 1984). SGP also meets the objectives of encouraging self-directed learning, devising plans of action for patient problems, and independent thinking. The students practice self-directed learning in two settings: as an individual outside of class and as a member of a group in the class. Not only does the SGP student pursue knowledge on his or her own to meet specific learning goals, but s/he also translates that learning into group action.

Discussion of basic science content in SGP occurs in a non-linear fashion as opposed to the linear, didactic coverage of traditional, lecture-based instruction. Students spend most of their time clarifying basic science concepts both within and out of the context of clinical problems. One-seventh of the class time is spent by students structuring their classroom learning (i.e. planning the session). Because students balance their learning between the acquisition of cognitive skills and knowledge, their content coverage is limited, but significant. This limited coverage may cause student anxiety in the face of external assessments such as the USMLE I that favor broad content knowledge of multiple domains.[4] The "less is more" rule may apply to content coverage in SGP. The students are engaged in goal-driven inquiry that encourages the manipulation and reality-testing of basic science knowledge. These processes may be essential the development of expertise (VanLehn, 1996). Students cover less content, but with a greater understanding cultivated through clarification of knowledge.

Clarification in SGP places the medical student on the path towards medical expertise. Research in medical expertise suggests that experts draw on a broad, well-integrated knowledge base for their decision-making. While SGP does not provide broad content knowledge, it does support active integration of knowledge. Two of the main intentions of PBL are to make students better problem-solvers and to make them self-directed learners. We have already discussed the latter. What is "good problem-solving"? Studies of medical cognition can only approximate the requirements for good problem-solving as yet. While expertise seems knowledge- and experience-dependent, we can only

[4] Interestingly, the USMLE I has an explicit goal of fostering the active contemplation of basic science concepts, a goal of SGP and PBL alike. The actual format of the exam seems to undermine this learning objective of the NBME.

guess at the decision-making processes that actually direct the expert from problem data to diagnosis with accuracy and speed. By encouraging active, self-directed knowledge acquisition, SGP engenders students to build meaningful networks of basic science knowledge grounded by clinical examples. This seems to parallel the theory of knowledge encapsulation in the development of expertise (Boshuizen & Schmidt, 1992) and most other cognitive theories.

Small Group Process also encourages pro-social behavior that, although not part of a strict model of medical cognition, fulfills the humanistic educational objectives set by the Association of American Medical Colleges and other physician groups (Finnochio et al., 1995, AAMC, 1984). Working with others may or may not change what a student thinks about other human beings. However, SGP does impact *how* that student works with others. Listening and contributing in a cooperative activity fosters communication skills that are essential to compassionate care. Interrupting, talking over, and disregarding classmates is unacceptable. Acknowledgment of the group's goals (external goals) as superseding one's own goals (internal goals) in the classroom process parallels the doctor-patient interaction. While one may have personal feelings as a physician, the clinical interaction should be focused on patient goals (AAMC, 1984; Katz, 1984). SGP may thus contribute to the acquisition of communication skills in raising one's sensitivity to external goals that base compassionate care. Most physicians are actively involved in collaborative endeavors in providing patient care. Working with others is an integral part of clinical practice.

Among the numerous goals set for medical expertise, one can abstract three basic categories of objectives: learning, problem-solving, and compassion. Learning is the capacity to pursue and maintain expertise. Problem-solving is actively engaging a patient problem mindfully. Compassion is being able to engage the patient as well as the problem. SGP appears to encourage learning in all of these categories. Considering the directionality and knowledge-dependency of expert medical cognition, it is doubtful that SGP, or any other teaching method, explicitly stimulates the novice to think in the same fashion as an expert (Patel et al., 1994; Elstein, 1978). However, SGP does encourage knowledge-testing that is essential to the development of expertise in a domain (VanLehn, 1996). Most importantly, SGP encourages learning within the context of both individual and group goals. John Gardner (1964) believes the main goal of any educational process is to develop "habits of mind... that will be the instruments of continuous change and growth" by the learner. If this be the case, then SGP, as recognized by students, instructors, and this study does indeed foster habits of mind that contribute to compassionate, mindful medical care.

IV. Recommendations for the JMP

In an era of mass education, the JMP stands with a seemingly ever-shrinking group of schools that value student-centered education. Its small size makes it fertile ground for educational innovation, research, and change. SGP has taken root in the JMP. It is an incredibly valuable teaching method for the reasons enumerated above. This section's purpose, albeit brief, is to use the findings of this preliminary study of SGP to highlight potential areas of change within the three-year JMP pre-clinical curriculum.

Recommendation 1: Ensure broad content coverage for students

Small group process is currently being used to teach the content areas of Physiology and Neurobiology in sum. The non-linearity of SGP makes content coverage seem sporadic and incomplete to the novice. It is difficult for a learner to transition to SGP, having acclimated to a system that values knowledge being given by an expert rather than discovered by a novice. Furthermore, it seems better to cultivate active manipulation of concepts once the learner possesses a relatively broad knowledge of a domain. Based on the models of medical cognition, an integrated knowledge may contribute significantly to expertise. Only through application does one test the generalizability of basic science concepts. Thus, a curriculum that supports both knowledge acquisition and utilization, as Whitehead might have it, seems best for quenching the fires of external assessments while concurrently stimulating higher order thinking.

Recommendation 2: Allow for self-directed learning in the curriculum

Being a close relation of UCSF allows us access to certain privileges. One of those is access to the experts who teach in the more traditional, content-oriented fashion of undergraduate medical education. Given the limited resources of the JMP and the limited time of its faculty, it may be most economically sound to let technology carry some of the onus of providing content coverage to our students. Technologies such as video-conferencing, video-simulcast, and video-taping would permit our students free access to the UCSF Physiology and Neurobiology classrooms. In addition, students could choose their own times to watch the lectures or, using an educational contract with a faculty member, follow their own course of completely self-directed study. This would increase the number of open hours in the first year curriculum by six hours per week in the Fall term and three hours per week in the Spring term. These hours could be used for thesis preparatory work, GSIships, community work, or the like.

Recommendation 3: Ensure cognitive skill acquisition in the JMP

Let us not forget our uniqueness! SGP has a great deal to offer our students. However, as long as it remains in a role that demands broad content coverage (as the names "Physiology" and "Neurobiology" suggest) students will be frustrated. Two of the most important functions of SGP are: (1) fostering application and integration of basic science knowledge in the context of clinical problems; and (2) stimulating pro-social behavior that values the humanism in, not just the science of, medical care.

SGP might be best used as a distributed teaching method across the entire three year JMP curriculum. It could be used to stimulate the integration of basic science concepts in multiple domains that are often temporally isolated from one another in a traditional curriculum. Monthly SGP classes centered around cases written by clinicians and basic science faculty could serve as focal points for group work and broader thinking. While courses could continue assessments directed at informational content, SGP sessions could be a form of on-going assessment of group work skills, self-directed study skills, and applied science skills.

Four blocks of subject areas could be used to organize the content coverage in the SGP sessions:

Block 1	anatomy, biochemistry, histology, physiology
Block 2	neurobiology, neuroanatomy
Block 3	pharmacology, microbiology
Block 4	drawing from blocks 1-3 in the context of: medicine, pathology, physical diagnosis, microbiology, psychosocial studies

SGP would not be a substitute for content coverage. Rather, it would serve as a series of focal points for students to take the enormous volumes of information they learn and make some of the concepts within those volumes meaningful and related to each other in a cooperative setting.

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Chapter Six: Appendices

Appendix A

Form documenting student's informed consent to participate in educational research project:

My name is Kimo Takayesu. I am a graduate student at the University of California at Berkeley and a medical student at the University of California at San Francisco.

I would like you to take part in my research. It focuses on increasing student awareness of his/her cognition in group problem-solving situations, thereby improving his/her problem-solving performance.

If you agree to participate in my research, I will video and audio tape your Neurobiology (HMS 211) class sessions. I will not intervene in the classroom process. I will be transcribing the dialogue from the classroom and analyzing it to identify various problem-solving roles present in the group. This analysis will be relayed to you, your classmates, and your instructors during the semester in hopes of modifying your problem-solving strategies in group process as well as aiding in the design of lessons that emphasize the use of your Neurobiology knowledge in problem-solving situations.

What benefits can this research offer me?

A typical frustration encountered in this learning format is that a great deal of time is often spent on interaction and consensus-building rather than actual problem-solving or informational learning. My research is meant to identify these learning process problems and facilitate their solution through open dialogue on the process of learning and problem-solving.

The recording and analysis of your classroom will help to design instructional methods that improve the problem-solving skills of the group. Data gathered from the sessions will help target weak areas of problem-solving that are often sources of frustration in the group process problem-solving method.

What risks does this research pose to me?

Video and audio taping may make you uncomfortable or excessively self-aware of what you are saying, hindering your participation. It may also encourage wanton participation for the sake of pleasing the instructors and/or the investigators. I hope to minimize these adverse effects by the following:

(1) Anonymous criticism sheets will be provided to students at the beginning of the semester. Students may use these sheets at any time during the process to identify their discomforts to the teaching assistant and/or the instructors.

(2) Students are free to call the teaching assistant (Kimo Takayesu) at home at any time if they are feeling uncomfortable with the process and wish to discontinue participation.

(3) Students will be provided with the teaching assistant's email address for feedback.

(4) The several Group Meetings with the teaching assistant will have an "open comments" period for discussion of the research and its positive and/or negative effects on students.

(5) Feedback from the above channels will be responded to personally and/or in a weekly newsletter format to the group to keep the class updated on concerns/issues with the research.

What about my privacy?

Prior to any recordings, you will be presented with a release form permitting the use of any recordings for educational research purposes only.

All recordings will be kept confidential. They will be stored in the Health and Medical Sciences (HMS) office in 570 University Hall in a locked cabinet. Backups of any recording, if made, will be stored in this location as well. Sessions will be noted by class (Neurobiology), date, and time on the exterior of all tapes, whether video or audio. The key to the cabinet will be held by Alan Steinbach and a copy will be held by Kimo Takayesu.

During transcriptions of the video and audio, all tapes in use will be stored in the locked desk of Todd Shimoda or Kimo Takayesu and will be returned to the HMS office as soon as transcriptions are done. Any transcriptions, whether hard copy or on diskette, will be locked in either of these locations. Transcriptions will refer to students by a false name or number to protect identities.

Your participation in this research is strictly voluntary. You are free to refuse to take part in the project at any time before or during the semester. Whether or not you participate will have no bearing on your academic standing at UC Berkeley or at UCSF.

If you have any questions about the research, please call me, Kimo Takayesu, at (510) 525-7413. If you agree to take part in the research, please return a signed copy of this form to me by January 16, 1996. You may keep the other copy for your future reference.

Thank you for your time and your consideration of this matter.

I, ____________________________, have read this consent form and agree to take part in the above research project.

________________________________ ________________________

Signature Date

Appendix B
Neurobiology Learning Workshop -- Session #1

Learning Objectives for Session:
1. To develop an explicit understanding of the skills essential to one's concept of an ideal physician.
2. To create learning objectives for the Neurobiology class that target some/all of the identified skills.
3. To incorporate these skill-based learning objectives into the current forms of assessment of the Neurobiology class.
4. To understand how the in-class cooperative learning process can be seen as a model of the individual problem-solving process.

A. What are the CHARACTERISTICS of an ideal physician? (Objective 1)

Please use the space below to brainstorm.

B. What SKILLS do each of these characteristics require on the part of that ideal physician? (Objective 1)

Use the space below to formulate a list of skills.

C. Think about the Neurobiology classroom. Go back to the skills list and circle the skills that Neurobiology class can help you to obtain/improve. (Objective 2)

D. Now try to prioritize the circled skills by grading them "1" for the most important/relevant skills to develop using the Neurobiology class, "2" for intermediate skills, and "3" for the least relevant skills. (Objective 2)

E. How can you use the following forms of assessment in the Neurobiology class to work on these skills? (Objective 3)

• "Journals" of learning issues (with paired peer review)
• Out-of-class preparation for the classroom

• In-class process of group-problem solving

What other activities could you add to the above list of assessments that would address the skills not already covered? These may be added to your contract as additional forms of *personal* assessment. (Objective 3)

F. Roles in Cooperative Learning (Brown & Palinscar, 1990s):

1. Contributor - offers ideas/concepts to the group

2. Executive - directs learning towards an established goal

3. Critic/Evaluator - compares/contrasts ideas in pursuit of established goal

4. Assimilator - links ideas or concepts in forming a more integrated picture of problem/solution

5. Recorder - keeps track of ideas/concepts and learning issues raised during problem solving session

What TARGETED SKILLS are subsumed by these roles?

Are these "roles" necessary components of successful individual problem-solving? (Objective 4)

Appendix C
Neurobiology Learning Workshop -- Session #1

In the first session, we accomplished the following learning objectives:

1. *characterized* personal conceptions of an "ideal physician"
2. *abstracted skills* from the model of (1)
3. identified skills *relevant* to the Neurobiology class
4. synthesized these skills into a set of *skill-based learning objectives* for the class
5. grouped the skill-based learning objectives with the *journals, in-class process, and out-of-class preparation* according to their relevance to that activity (see below)

Rank 1 (most relevant to Neuro class)	Activity for obtaining/improving skill
Communication: to listen to others and express oneself well; to learn teaching skills	In-class process
Handling information/database management: to be able to access resources (i.e. medical journals) well	Journals, out-of-class preparation
To be able to **cope emotionally and respectfully** with physical and mental boundaries; to be respectful of others and be responsible for one's own feelings	In-class process
To be **aware of one's own knowledge**; to be able to admit when one is wrong	In-class process, (journals, out-of-class preparation)
To be able to **meet work goals**	In-class process, journals, out-of-class preparation
To be able to **manage time** efficiently	In-class process, out-of-class preparation
To be able to **problem-solve** well	In-class process, out-of-class preparation
To be able to **laugh**	In-class process
To learn **writing skills**	Journals, out-of-class preparation

Rank 2 (semi-relevant to the Neuro class)

To be able and willing to see **variables that are not medical** that impact people's lives	<not assigned>
To be able to **follow the group's goals**	In-class process
To be **empathic**	In-class process
To have/portray a **warm composure**	In-class process
To be **patient**	In-class process

Appendix D

Neurobiology Midterm Evaluation:

Purpose: to evaluate how well/poorly the structure of the Neurobiology class (both in-class and out-of-class) is facilitating students' fulfillment of (1) student-set learning objectives, and (2) instructor-set learning objectives.

I. Open response section: Please comment on any successes/failures of the class that you have had in Neurobiology to this point. Use the back of this sheet if necessary.

II. Student-set Learning Objectives: Please state PERSONAL learning objectives that you perceive for YOURSELF indicating how well/poorly the Neurobiology class is meeting each one. If these objectives are already stated above, indicate so. Use the back of this sheet if necessary.

III. Student-set Learning Objectives: Please rate the level to which the Neurobiology class is addressing the following objectives as stated by your CLASS AS A WHOLE at the beginning of the semester.

Rating:
1 very poorly
2 poorly
3 fair
4 well
5 extremely well

Qualify any poor ratings by stating what changes might address these problems.

Primary Objectives	Rating	Comments
Communication: to listen to others and express oneself well; to learn teaching skills		
Handling information/database management: to be able to access resources (i.e. medical journals) well		
To be able to **cope emotionally and respectfully** with physical and mental boundaries; to be respectful of others and be responsible for one's own feelings		
To be **aware of one's own knowledge**; to be able to admit when one is wrong		
To be able to **meet work goals**		
To be able to **manage time** efficiently		
To be able to **problem-solve** well		
To be able to **laugh**		
To learn **writing skills**		

(III. Student-set Learning Objectives continued)

Secondary Objectives	Rating	Comments
To be able and willing to see **variables that are not medical** that impact people's lives		
To be able to **follow the group's goals**		
To be **empathic**		
To have/portray a **warm composure**		
To be **patient**		

IV. Instructor-set Objectives: Please rate how well the class is helping you to meet the learning objectives that the instructors feel are most important to their choice of small group process as an educational device.

Secondary Objectives	Rating	Comments
Present knowledge in the context of specific Neurobiological problems		
Use class meeting time to increase the perceived informational needs in a given area of Neurobiology		
Have mutual respect with an understanding of how diversity of learning styles, etc. contributes to being a good doctor		
Use self-directed study and information resources to meet the perceived needs raised in class		
Set learning goals and evaluate progress towards those goals		
Improve leadership skills in group work		

Learn how to communicate complex concepts in simplified terms		
Integrate knowledge into concise, understandable formats		
Improve ability to build consensus and give peer review		

Appendix E
Neurobiology End-of-Term Evaluation:

Purpose: to evaluate how well/poorly the structure of the Neurobiology class (both in-class and out-of-class) is facilitating students' fulfillment of (1) student-set learning objectives, and (2) instructor-set learning objectives.

Group Tutor's Name: ______________________

Your CODE NUMBER is: ____________________

I. Open response section: Please comment on any successes/failures of the class that you have had in Neurobiology this semester. Use the back of this sheet if necessary.

II. Student-set Learning Objectives: Please state PERSONAL learning objectives that you perceive for YOURSELF indicating how well/poorly the Neurobiology class helped you to meet each one. If these objectives are already stated above, indicate so. Use the back of this sheet if necessary.

III. Student-Generated Learning Objectives: Please rate the level to which the Neurobiology class has fulfilled the following objectives as stated by your CLASS AS A WHOLE at the beginning of the semester.

Rating:
1 very poorly
2 poorly
3 fair
4 well
5 extremely well

Qualify any poor ratings by stating what changes might address these problems.

Objectives Most Related to the Neurobiology Class	Rating	Comments
Communication: to listen to others and express oneself well; to learn teaching skills		
Handling information/database management: to be able to access resources (i.e. medical journals) well		
To be able to **cope emotionally and respectfully** with physical and mental boundaries; to be respectful of others and be responsible for one's own feelings		
To be **aware of one's own knowledge**; to be able to admit when one is wrong		
To be able to **meet work goals**		
To be able to **manage time** efficiently		
To be able to **problem-solve** well		
To be able to **laugh**		
To learn **writing skills**		

Objectives Partially Related to the Neurobiology Class	Rating	Comments
To be able and willing to see **variables that are not medical** that impact people's lives		
To be able to **follow the group's goals**		
To be **empathic**		
To have/portray a **warm composure**		
To be **patient**		

IV. Instructor-Generated Objectives: Please rate how well the class has helped you to meet the learning objectives that the instructors feel are most important to their choice of small group process as an educational device.

Objectives Basing Instructors' Choice of Teaching Method	Rating	Comments
Present knowledge in the context of specific Neurobiological problems		
Use class meeting time to increase the perceived informational needs in a given area of Neurobiology		
Have mutual respect with an understanding of how diversity of learning styles, etc. contributes to being a good doctor		
Use self-directed study and information resources to meet the perceived needs raised in class		
Set learning goals and evaluate progress towards those goals		

Improve leadership skills in group work		
Learn how to communicate complex concepts in simplified terms		
Integrate knowledge into concise, understandable formats		
Improve ability to build consensus and give peer review		

V. The Role on Evaluation in Neurobiology:

1. Did you find the explicit stating of instructor-generated learning objectives for the Neurobiology class helpful in guiding your learning?

1 2 3 4 5 (circle one)
[Not at all Very little Some Very much]

Please comment on the reason for your rating.

2. Did you find generating student-centered learning objectives for the Neurobiology class helpful in your learning process?

1 2 3 4 5 (circle one)
[Not at all Very little Some Very much]

Please comment on the reason for your rating.

3. To what extent did the Mid-semester evaluation of the classroom improve/worsen the success of the class for you?

Improved Worsened (circle one)

1 2 3 4 5 (circle one)
[Not at all Very little Some Very much]

Please comment on the reason for your rating.

4. How could the course evaluation process have better suited your learning needs and/or expectations (You may find it helpful to refer to the previous questions of this section)?

(structure of the class promotes this). I want to talk/study/work with others on these issues (class working well)"

"Learn neurobiology -- class is not meeting this too well. I really appreciate Alan's effort to remodel the course, etc. but the material is just so complicated that we often just need some sort of coherent integration!"

"Class is great. I am mot doing as much reading and note-taking as I should be, but this is true in all of my classes. I actually feel more on top of this class than most others, but that's not saying much. I think my biggest complaint is that we are so rushed for time that I can only address one of the ten or so big, important questions I develop each week."

"Learning the subject matter of Neurobiology to a level of that presented in the student syllabus. Becoming more comfortable with the ups and downs of participating in group process. I feel frustrated with the format of this course in relation to learning the subject matter. Discussion time is not enough to really hash things out. The lectures are even less efficient -- Alan's are not organized enough and Bowen's are not mechanistic enough. Given these limitations, the group process aspect of the class went well for me."

"One of my objectives was to feel comfortable enough with my level of knowledge to participate actively in class. I think that I and meeting this objective. Defined learning issues really help me with this. Another is to gain sufficient familiarity with the terms and concepts to understand textbooks and articles. I haven't tested this adequately, but the speed at which I can read and understand the text (big Kandel) makes me believe that I will be able to understand a lot of literature after this course. Another goal would be to increase my self-confidence in this domain of information and in group process. On both counts, I think the class is working."

"I am learning to work in a group better. I wish we had longer class discussions that were not interrupted by a lecture. I am enjoying the class but I feel that it tries to talk about lots of issues that are still very unclear."

"If I grow as an interacting person from this class that is great, but my main goal is to understand the brain and its integration of the body. I think this goal would be better met with [spending a full two hours on a topic then be given the next case pg. A]. One hour only gives time to taste the topic and get it maybe to the thalamus. The second hour would let it get to the cortex or maybe as a group more integration would occur."

"Have fun -- yes. Learn Neurobiology -- yes for the most part although there are a few sections that I don't feel strong about yet such as smell, taste, and how individual neurotransmitters are used. One thing this class structure is not good for is memorizing details -- but I don't know how important these are yet."

Secondary Objectives	1	2	3	4	5	Avg
To be able and willing to see **variables that are not medical** that impact people's lives		3	5	3	1	--
To be able to **follow the group's goals**[7]			4	5	2	3.8
To be **empathic**			4	6	2	3.8
To have/portray a **warm composure**[8]		1	3	6	2	--
To be **patient**			4	6	2	3.8

7 One non-responder

8 One response "3/2" interpreted as value of 2.

IV. Instructor-set Objectives: Students rated how well the class is helping them to meet the learning objectives that the instructors feel are most important to their choice of small group process as an educational device. [See Appendix C for comments]

Objectives	1	2	3	4	5	Avg
Present knowledge in the context of specific Neurobiological problems[9]		1	3	4	4	--
Use class meeting time to increase the perceived informational needs in a given area of Neurobiology[10]		2	3	4	2	--
Have mutual respect with an understanding of how diversity of learning styles, etc. contributes to being a good doctor		2	1	5	4	--
Use self-directed study and information resources to meet the perceived needs raised in class[11]		1	4	5	2	--
Set learning goals and evaluate progress towards those goals	1		3	7	1	--
Improve leadership skills in group work			2	5	5	4.3
Learn how to communicate complex concepts in simplified terms			5	5	2	3.8
Integrate knowledge into concise, understandable formats		1	5	5	1	--
Improve ability to build consensus and give peer review			1	8	3	4.5

[9] One response "4-5" interpreted as value of 4.
[10] One response "4+" interpreted as value of 4.
[11] One response "3+" interpreted as value of 3.

Summary:

The responses had considerable variation on a number of points. The purpose of the in-class time was particularly problematic. Some students found that the discussions helped raise questions that stimulated further exploration of the material in their own time. Others found that the class was informationally sparse and that the discussions did not increase their understanding or appreciation of Neurobiology. There was considerable variation the estimates of how well or poorly the class was addressing the objectives of ability to meet work goals, to manage time, to problem-solve, and to learn writing skills. This variability was also true of many of the instructor-set learning objectives.

Leadership skill, consensus-building skill, and communication skill were instructor-set objectives that were generally considered met by the group. There was also general consensus that the class is not teaching students how to handle information resources well. In addition, students consistently stated that the lack of enough discussion time was hampering the effectiveness of the class time. Some students found the lectures to be confusing or too general and suggested using the time for a more extended discussion.

Conclusion:

Two immediate areas for improvement are: (1) increasing students ability to use information resources other than their texts; and (2) setting clear, consistent goals for the in class time (i.e. should the time be for raising questions, presenting LIs, and/or discussing the case? how much time for each?).

Comments:

Primary Objectives	Comments
Communication: to listen to others and express oneself well; to learn teaching skills	"It's coming along gradually" (5) "Nice frosting on the cake but not a huge part of my objectives for this class - life, yes, this class, not really (too much other stuff" (5) "There is a feeling of being rushed that is inhibiting my freedom of expression" (3) "As always group process is good for this. But I often felt as if there was no time to speak or articulate my ideas." (4) "Great practice." (5)
Handling information/database management: to be able to access resources (i.e. medical journals) well	"Luckily I felt that I already had some of this" (2) "So much basic information to cover, never have time to really delve into journals" (2) "We only use our class resources (Kandel, etc.). There is not enough time to do these other things" (3) "I am unsure about what is considered 'current' information and which supplemental texts can be used" (2) "We are learning to access some info and not often other forms. Lack of time is the biggest problem" (3) "I am getting better at using textbooks as resources. I have not used other sources such as journals or neurology texts. I don't know if that is OK or not." (3) "I'm not doing it much" (4) "Haven't used a medical journal for anything yet. No time, and most things are in Kandel." (2) "This is necessary but we're not receiving a lot of instruction from the class" (3)

To be able to **cope emotionally and respectfully** with physical and mental boundaries; to be respectful of others and be responsible for one's own feelings	"Nice frosting on the cake but not a huge part of my objectives for this class - life, yes, this class, not really (too much other stuff" (5) "To the extent we don't feel rushed, and group process dynamics are at work, this works" (3) "I wonder if we are really learning to cope or if we are just getting used to each other's quirks" (3) "It is difficult but a great learning experience to have to come to every session and work regardless of how you feel." (4)
To be **aware of one's own knowledge**; to be able to admit when one is wrong	"Nice frosting on the cake but not a huge part of my objectives for this class - life, yes, this class, not really (too much other stuff" (5) "Nothing new here." (3) "Good atmosphere for this." (5)
To be able to **meet work goals**	"This is hard in general. I felt overwhelmed by everything in general, at least today" (3) "Not to be fresh, but I learned this in 2nd grade" (5) "I'm not sure if this means in class or out of class. In class is OK." (3) "We are not getting learning issues prepared well enough" (2) "Good, but at times of great fatigue I have a hard time knowing what to do." (4)
To be able to **manage time** efficiently	"What time?" (2) "Yes, we are definitely learning this" (4) "Time in group process could be managed slightly more efficiently but do we want to be robots?" (4)

To be able to **problem-solve** well[12]	"I think this class is good for this" (5) "Nice frosting on the cake but not a huge part of my objectives for this class - life, yes, this class, not really (too much other stuff). I think this is very important and don't think I get enough of this. The two hour format would give more time for us as a group to actually delve into problems" (3.5) "We have very little time to solve problems. There are very few problems presented." (2) "Time constraint. The hour is not enough to discuss LI, raise questions, and solve the case" (4) "Cases are excellent." (5) "Practice: self-confidence will help" (3)
To be able to **laugh**	"Not that I ever needed much help" (5) "Nice frosting on the cake but not a huge part of my objectives for this class - life, yes, this class, not really (too much other stuff" (5)
To learn **writing skills**	"This is a good class for this with student reviews of LI" (5) "Nice frosting on the cake but not a huge part of my objectives for this class - life, yes, this class, not really (too much other stuff" (3) "Hard to tell, my evaluator did not evaluate my writing (of the LIs)" (3) "With the learning issues - if our signer offers edit well" (5) "We aren't really doing style editing" (2)

[12] One response "3.5" interpreted as value of 3.

Comments:

Secondary Objectives	Comments
To be able and willing to see **variables that are not medical** that impact people's lives	"We haven't touched on this." (2) "Case-based format allows for this a little" (3) "This class had very little to do with it, except for the guest speaker" (2) "Once again, not enough time" (3) "I don't think this is a focus of the course. However, I think we could maybe look at emotional influences on other aspects of the nervous system later in the class." (3) "We've really strayed away from the non-medical perspective." (3) "No discussion on this topic yet." (2) "See everyone as they have their good and bad days -- check in and check out is essential." (5)
To be able to **follow the group's goals**[13]	"They are not set very well" (3) "I would like superfluous comments about evolution - god - etc. to be limited (unreadable word) how we spend out time." (3)
To be **empathic**	"These are not my goals for Neurobiology, they are my goals for being a doctor but I don't feel these are my main goals here" (4) "Not specific to this class" (4)

[13] One non-responder

To have/portray a **warm composure**[14]	"These are not my goals for Neurobiology, they are my goals for being a doctor but I don't feel these are my main goals here" (4) "Not specific to this class" (4) "I don't think I have addressed these. I suppose the class is encouraging me to use them..." (3)
To be **patient**	"These are not my goals for Neurobiology, they are my goals for being a doctor but I don't feel these are my main goals here" (4) "Not specific to this class" (4) "How can we learn this?" (3) "I don't think I have addressed these. I suppose the class is encouraging me to use them..." (3) "I do not know if we are truly being warm and patient or if we are just specifically being happy yet intentionally becoming emotionally detached from the course or its goals or our personal goals for the course." (3)

[14] One response "3/2" interpreted as value of 2.

Comments:

Objectives	Comments
Present knowledge in the context of specific Neurobiological problems[15]	"I think group process is great for this - we do it all of the time" (5) "There is very little knowledge out there about Neurobiology" (3) "The case gets lost in the shuffle because of the short time frame" (3) "Knowledge is not really presented" (3)
Use class meeting time to increase the perceived informational needs in a given area of Neurobiology[16]	"I think group process is great for this - we do it all of the time" (5) "Very good, but I don't feel like the information is out there necessarily" (4) "The class time is to often used for basics" (3) "I find that the class increases insecurity about the subject as much as it increases perceived info needs." (3) "Maybe more time should be spent actually learning, rather than figuring out what we need to know." (3) "Learning issue generation going well." (4+) "Class discussions are too sporadic, disorganized. Also, I thoroughly prepare so I learn a lot out of class. I do, however, learn some. More discussion would be helpful!" (2)
Have mutual respect with an understanding of how diversity of learning styles, etc. contributes to being a good doctor	"Hmm... I am trying to do this through my thesis" (3) "We have no time to explore various learning styles" (2)

[15] One response "4-5" interpreted as value of 4.
[16] One response "4+" interpreted as value of 4.

Use self-directed study and information resources to meet the perceived needs raised in class[17]	"I think group process is great for this - we do it all of the time" (5) "It would be more if I was more excited about the material" (3) "What would be really cool would be if Bowen would compile a list of specific resources as we go along based on the perceived needs raised in class. This could be a running resource for out class and future classes. Student could add to it." (4) "Not enough time on weekends to do extra questions raised when busy doing the next LI" (3) "There is no system in place to give back to the class. How do we share our LIs before the class is over?" (4) "The LI format this time does not seem to work that well because the group never gets to have the whole answer." (2)
Set learning goals and evaluate progress towards those goals	"Hasn't happened." (1) "Would be better to have more sessions on each case so we could re-evaluate learning issues a greater number of times" (4) "How do we jointly evaluate progress towards goals in this class?" (4)
Improve leadership skills in group work	"I'm forced to" (4) "It is hard to lead during an extreme time crunch" (3) "I appreciate the chance to learn to lead discussions" (5) "The facilitator position is interesting" (4) "I'm not sure how this could improve because I am not sure what it entails." (3)

[17] One response "3+" interpreted as value of 3.

Learn how to communicate complex concepts in simplified terms	"I think group process is great for this - we do it all of the time" (5) "We never really got to the complex issues" (3) "We try I think" (4) "We are too frazzled sometimes to really do this" (3) "It would be better if we had a better grasp of the complex concepts before simplifying" (3) "But isn't it important to learn details too? Sometimes things gets too simplified i.e. 'think of an action potential as ions moving across the membrane'" (3) "If lectures by instructors need things other than "black box" to describe things, I might learn alternative way to simplify terminology." (3)l
Integrate knowledge into concise, understandable formats	"Don't feel we have much integration time" (2) "Concise cannot handle detail, can it?" (3) "Are we being concise in our learning issues? We may be overboard." (4) "We really don't have time for quality sum-ups" (3)
Improve ability to build consensus and give peer review	"The learning issue sign-off is a good idea" (5)

Appendix G

Neurobiology End-of-Term Evaluation:

Purpose: to evaluate how well/poorly the structure of the Neurobiology class (both in-class and out-of-class) is facilitating students' fulfillment of (1) student-set learning objectives, and (2) instructor-set learning objectives.

Group Tutor's Name: ____________________________

Your CODE NUMBER is: __________________________

I. Open response section: Please comment on any successes/failures of the class that you have had in Neurobiology this semester. Use the back of this sheet if necessary.

"I continue to learn a lot about working in a small group and a ton about facilitating. I don't know how much I learned about the subject matter, however. I really haven't concluded as to whether that is OK or not. It really does feel like a trade-off was made, however." [NBS 05]

"I really think that the class was a smashing success. I loved it. I feel that I learned a lot of material, and truly enjoyed the process of learning. This is in marked contrast to my experience in Neuroanatomy class this semester. I would like Alan to know that I think the modest increase in structure (compared with physiology) led to an enormous dividend in results." [NBS 03]

"I really enjoyed the subject matter. I was frustrated with group process on occasion but I loved the material. My familiarity with the topic let me get over my intimidation. I felt that the learning issues gave us an excellent opportunity to explore topics in depth and synthesize material. I thought writing up learning issues was a wonderful idea. It permitted us at times to move away from a detail-oriented topic and move the group process forward without feeling like we were shirking important issues. I also think using the issues we generated for a final is a great idea, although I don't know about this board-style thing." [NBS 11]

"My one success was finding my self-esteem that I had lost somewhere during Physiology. I feel I am able to speak up more and 'risk it'." [NBS 08]

"In many ways this course has given me the opportunity to re-evaluate previous knowledge of this subject in new ways by asking new questions of myself and responding to those that people addressed. I do worry that too much time was allocated to learning some fundamental basics as this precluded possible opportunities to address important functional issues such as memory, sleep, and development as it relates to neurobiology. Despite these short-comings, I did enjoy the course." [NBS 01]

"I thought the class went well. I wished I'd had the Big Kandel very often. I really liked the format after the midterm." [NBS 07]

"I didn't learn Neurobiology as well as I had hoped, but I think that it was kind of interesting to raise different issues with classmates. I think that lectures didn't help very much -- most of the time they weren't very coherent or were too easy or too advanced or went off on tangents. I really liked the demonstrations, though, like the pinwheels and magic eye and Bowen's videos of the Parkinson's patients." [NBS 06]

"Successes - we made it through without people feeling as hurt or unhappy as Physiology. We bonded as a class. People in general are better facilitators and group process participants that in physiology.
Failures - This course was I think an inadequate introduction to Neurobiology. It decreases my confidence that this particular format for learning basic, but complex, material is ideal. There is not enough drive to get students to do their best work especially when we have many other things to do for other classes." [NBS 14]

"Successes: A better understanding of Neurobiology. A very positive group process experience in the second half of the semester. We fished out how to get things done. An appreciation for the BRAIN! More confidence reading and writing on this topic. The changes in format after the midterm (lecture, etc.).
Failures: My memory for the details is not good, and this frustrates me. Also our final exam routine is turning into a big fiasco with too many parts." [NBS 04]

"Success: Learning group skills. Learning how to explain/present. Learning how to pick learning issues.
Failure: I don't know. I still feel that concise, authoritative material is an unfortunate thing to give up in doing group process." [NBS 02]

"The class was great. I failed to fall in love with the topic, or to appreciate information gathering tools or the current research in the field. Other wise, I loved the class and it met many of my goals. I liked the explicit learning contract." [NBS 12]

"I thought the class was fantastic, especially the last few sessions; I was sorry to see it end because it seemed like we were all just getting the hang of it." [NBS 10]

<u>II. Student-set Learning Objectives</u>: Please state PERSONAL learning objectives that you perceive for YOURSELF indicating how well/poorly the Neurobiology class helped you to meet each one. If these objectives are already stated above, indicate so. Use the back of this sheet if necessary.

"I think I finally learned how to motivate myself to work, before class, to a high level of familiarity with the subject. The result was that I loved the sessions because I was really involved in the discussion. I will really miss group process." [NBS 03]

"Honestly, my objective was to get through the class with my sense of confidence and with my enjoyment intact. That was accomplished. I felt that we all got better at group process and I am continually impressed that we are still getting along. I also felt that I learned and retained enough information to have a conceptual framework from which I could actually speak or synthesize. I don't know if that makes sense but it was important for me to be able to speak comfortably in class and I feel that I learned enough and felt safe enough to do that." [NBS 11]

"Struggling with the amount of time I spent preparing for class, managing vast amounts of informational resources, I spent less time the second half of the semester. I'm glad that I did this: I still felt very prepared -- which was good. And, since the midterm I tried to address my own personal needs within the group so maybe this course has helped me learn to be assertive in this way. And, communications were fine." [NBS 01]

"I learned Neurobiology and group interaction skills." [NBS 07]

"Learn Neurobiology well. I kind of hoped that Neurobio would make Neuroanatomy easier but I think that it was difficult to get big pictures when the only real work we ever had to do was focus on our individual learning issues." [NBS 06]

"I wanted to learn Neurobiological concepts and cases with some degree of rigor. Class discussion did not promote this and neither did the learning issues which seemed too random and spread out to give that knowledge a firm skeleton to rest on. I feel that a conceptual foundation based on better understanding of the material is better than using cases as a focal point for hanging information on. The communication and empathy aspects are OK though. However, it was frustrating that rarely was everyone really prepared enough to participate fully, which is essential to group process." [NBS 14]

"I had wanted to learn Neurobiology to the level of the student syllabus (Unfortunately, after the midterm I stopped reading the syllabus because I realized I always read the text in addition anyway). Certainly I don't remember everything in the syllabus but I feel comfortable with the material in it.
Also I had wanted to be more comfortable with the ups and downs of group process. But my group this time had hardly any downs. We worked very well together and our process went very well, even though we spent very little time discussion process issues. As far as I can remember I only had one really bad day." [NBS 04]

"Get better at working in groups -- great
communication skills --great
self-articulation -- great
self-motivated study -- great
facilitating group process -- great

"Get an understanding of some of how the brain works -- O.K.

"Get a knowledge of the various research in the field -- bad" [NBS 12]

"Learn Neurobiology. Have productive, stimulating sessions that everyone could enjoy and learn from." [NBS 10]

III. Student-Generated Learning Objectives: Please rate the level to which the Neurobiology class has fulfilled the following objectives as stated by your CLASS AS A WHOLE at the beginning of the semester.

Rating:
- 1 very poorly
- 2 poorly
- 3 fair
- 4 well
- 5 extremely well

Qualify any poor ratings by stating what changes might address these problems.

Objectives Most Related to the Neurobiology Class	1	2	3	4	5	Average
Communication: to listen to others and express oneself well; to learn teaching skills				9[18]	3	
Handling information/database management: to be able to access resources (i.e. medical journals) well	1	5	3	3		
To be able to **cope emotionally and respectfully** with physical and mental boundaries; to be respectful of others and be responsible for one's own feelings				8	4	
To be **aware of one's own knowledge**; to be able to admit when one is wrong			1	5	6	
To be able to **meet work goals**			1	8[19]	3	
To be able to **manage time** efficiently		1	1	7	3	
To be able to **problem-solve** well		1	2	5	4	
To be able to **laugh**				4	8	

[18] One response of "4.5" was interpreted as a value of 4.

[19] One response of "4/5" was interpreted as a value of 4.

To learn **writing skills**			5	3[20]	4	

Objectives Partially Related to the Neurobiology Class	1	2	3	4	5	Average
To be able and willing to see **variables that are not medical** that impact people's lives		3	3	5	1	
To be able to **follow the group's goals**				11	1	
To be **empathic**			1	10	1	
To have/portray a **warm composure**[21]			2[22]	7	1	
To be **patient**			7	3[23]	2	

IV. Instructor-Generated Objectives: Please rate how well the class has helped you to meet the learning objectives that the instructors feel are most important to their choice of small group process as an educational device.

Objectives Basing Instructors' Choice of Teaching Method	1	2	3	4	5	Average
Present knowledge in the context of specific Neurobiological problems			4	3	5	
Use class meeting time to increase the perceived informational needs in a given area of Neurobiology			2	7	3	
Have mutual respect with an understanding of how diversity of learning styles, etc. contributes to being a good doctor			1	8[24]	3	

[20] One response of "4.5" was interpreted as a value of 4.
[21] Two non-responders.
[22] One response of "3/4" was interpreted as a value of 3.
[23] One response of "4.5" was interpreted as a value of 4.
[24] One response of "4.5" was interpreted as a value of 4.

Use self-directed study and information resources to meet the perceived needs raised in class		1	4	5[25]	2	
Set learning goals and evaluate progress towards those goals			2	5	4	
Improve leadership skills in group work				8[26]	4	
Learn how to communicate complex concepts in simplified terms			3[27]	5	4	
Integrate knowledge into concise, understandable formats			1[28]	8	3	
Improve ability to build consensus and give peer review			1	7	4	

V. The Role on Evaluation in Neurobiology:

Scale: 1 [Not at all; 2 Very little; 3; 4 Some; 5 Very much]

Question:	1	2	3	4	5	Average
1. Did you find the explicit stating of instructor-generated learning objectives for the Neurobiology class helpful in guiding your learning?		3	3	5	1	
2. Did you find generating student-centered learning objectives for the Neurobiology class helpful in your learning process?		1	2	5	4	

[25] One response of "4.5" was interpreted as a value of 4.
[26] One response of "4.5" was interpreted as a value of 4.
[27] One response of "3/4" was interpreted as a value of 3.
[28] One response of "3/4" was interpreted as a value of 3.

3. To what extent did the Mid-semester evaluation of the classroom improve/worsen the success of the class for you?		2	3[29]	3	4	

4. How could the course evaluation process have better suited your learning needs and/or expectations (You may find it helpful to refer to the previous questions of this section)?

"I think the course evaluation would have helped more if I had forced myself to re-look at it, as Kimo suggested. I just never had the time. I think that the small quantity of available time was the biggest barrier to my learning." [NBS 05]

"Um, not really clear to me how they were used. I thought they were just for your study." [NBS 03]

"I thought the course evaluation process was actually quite helpful and useful. I'm not sure how it could have better suited my needs." [NBS 11]

"I would have liked to watch a video of a particular time in which I was (a) 'absent' or (b) extremely present or (c) hindering SGP [small group process] (d) facilitating SGP, or etc." [NBS 08]

"I'm not sure. To be honest, this process was a bit exhausting and efforts to make evaluations as minimally [maximally?] time efficient as possible would be great." [NBS 01]

"A final testing method (exam) that was known about from the beginning (the format and extent) would have been more useful at motivating me in a more structured personal learning style." [NBS 07]

"How about interviews with two students and the professor. That might be interesting. (The one student/two prof's approach was not the most friendly thing for students I think)." [NBS 14]

"This works well." [NBS 04]

"Maybe give more examples." [NBS 02]

"Some sort of summary of what we were "supposed" to know at that point might have been helpful." [NBS 10]

[29] One response of "some" was interpreted as a value of 3.

Appendix H
Self-Reported Student Learning Styles.

Statement	pole	extremely	moderately/ slightly	neutral	moderately/ slightly	extremely	pole
1. Situations in which I learn best tend to be	Active (i.e. engaged in a task)	5	5	0	1	0	Passive (i.e. listening to a presentation)
2. I learn best when	My teacher solves my problem	0	0	0	11	1	When I solve my problem
3. If a question arises when learning a concept in class, I prefer to	Trust a hunch in order to continue	1	3	2	6	0	Answer the question before continuing
4. When I learn, I tend to	Have strong feelings/emotions	1	9	1	1	0	Be quiet and reserved
5. When I learn, I tend to	Listen/watch carefully	0	4	1	7	0	Talk/steer the group's learning
6. I learn best when I	Model concepts in my head	1	4	4	3	0	Build a concept interactively
7. When I learn a topic	I like to approach it from many angles at the same time	0	7	2	3	0	I like to work along a single line of thought at a time
8. When learning a concept, I tend to	Use my intuition to guide my thinking	0	6	1	5	0	Use an existing, concrete model to guide my thinking
9. When learning in a group, I learn mainly from	Observing and listening to others	0	1	2	8	1	Talking with others
10. I learn best from	Rational theorizing	0	3	1	7	1	Using concepts in a "real world" situation

Appendix H (continued)

11. When working with others in a group, I tend to	"Jump in" with ideas as they come to mind	2	6	1	3	0	"Hold back" and formulate ideas before stating them
12. I am most happy with a class when I leave	Having thought about and discussed several concepts generally	2	2	3	5	0	Having a deep understanding of a single concept
13. I tend to spend my time outside of classes	Reading about the topic of the next class	3	7	0	2	0	Reading about the previous topic to "fill in" the gaps from the last class
14. A discussion is the most productive for me when the group	Answers specific questions about a topic that came up when studying outside of class	3	7	2	0	0	Raises questions about a topic for study
15. Hearing other people discuss a topic in a class that I already understand	Frustrates me because I already understand it and would rather go on	0	3	0	5	3	Engages me because I can re-evaluate my understanding of the topic

Appendix I

Table comparing the NBME content items for the USMLE I to Neurobiology SGP coverage.

NBME	Neurobiology
• functions of neurons, synapses, and regulatory processes	- neuromuscular junction - acetylcholine and acetylcholinesterase function in the NMJ - the dependence of acetylcholine release into he NMJ on Ca - anterior horn cell - role of the Na/K ATPase in establishing and maintaining resting membrane potential - effect of monovalent cations (K, Na, Cl) on membrane potential - the role of intracellular proteins in resting membrane potential - the membrane as a capacitor for separation of charge - leaky membrane channels v. voltage-gated membrane channels - role of cellular homeostasis in resisting extracellular ionic changes - differences in resting membrane potential and NMJ morphology between smooth and skeletal muscle - post-synaptic neurotransmitters of the sympathetic and parasympathetic nervous system
• sensory systems: signal transduction	- Nernst potentials for K and Na - action potential v. membrane potential - action potential v. EPSP v. IPSP - the Goldman equation - the function of the voltage-gated channel - threshold

• sensory systems: vision	- visual pathway from retina to occipital cortex - hemifields of the retina - patterns of visual defects based on location of lesion in the visual system (i.e. homonymous hemianopsia) - on-center v. off-center cells of the retina - subcortical v. cortical processing of visual information - magnocellular v. parvocellular pathways of vision (at the retina, lateral geniculate bodies, and cortex) - organization of the lateral geniculate body (contra- and ipsilateral inputs) - organization of the cortex into Brodman's areas - function of association areas in the parietal cortex - function of Brodman's areas 5, 7, 17. - role and anatomy of the lateral geniculate body and superior colliculi in vision - retinal ganglion cells (M and P subtypes) - characteristics of objects: form, movement, color - summation of signals at each level of the visual system - abstraction of contrasts leading to perception of edges by the visual system (retina, lateral geniculate, area 17 simple, area 17 complex, association cortex) - interblob (form and depth) v. blob (color) cortical area 17 - rectilinear v. center-surround summation of visual input - connectivity of cells at levels of the visual system (bipolar cell, retinal ganglion cells, geniculate cell, stellate cell of 4c-beta, cortical simple cell, cortical complex cell) - definition of cortical maps - definition and structure of hypercolumns - pyramidal cell layers of the visual cortex (layers 4c-beta and 5) - connections between hypercolumns summate regions of the visual field (ipsi and contralateral) to give whole image
• sensory systems: control of eye movements	- role of pretectum in pupillary reflex - saccadic movement - tectocerebellar tract

• other	- effect of hypernatremia on cell excitability - the physiology of hydrochlorothiazide - effect of hydrochlorothiazide on resting membrane potential and the CNS - role of bone metabolism in serum calcium levels - strength grading in neurologic disease - pre-central and post-central gyrus function and somatotopic organization - the definition and diagnosis of stereognosis - extinguishing - split brain experiments - definition of photophobia - electrophysiology of the EEG - definition of constructional apraxia - pathology of left-sided neglect - PET scan v. CT scanning in brain imaging - compression/local irritation of nerve tracts can cause firing and symptomatology relating to tract involved (e.g. visual disturbances due to impingement on the optic radiations by a tumor) - phantom pain - confrontational testing in neglect syndromes - relational anatomy of the parietal lobe, optic chiasm, and optic radiations - sensory innervation of the dura mater - activity of the visual system components during sleep and dreaming

Appendix J
Excerpts from two classes exemplifying activities in SGP:

Information resource discussion

S1: Can I just ask questions? Are other people going to read the rest of the vision stuff, or not?

S2: Yeah.

S1: Yeah.

Tutor: I think it's safe to say that the discussion next time should include references to, and in relation to the case, is... you know, why and how does the case work, but too, in general, how does cortical video processing work.

S2: What syllabus is that though, I mean what syllabus chapters is that? Is there not one for cortical visual processing?

S1: It's Nick's. It's really brief.

Tutor: It is. And part of the reason for that is that baby Kandel has a really good section on that, so it does force you to borrow a copy of it and...

S3: Instead of the big Kandel?

Tutor: No big Kandel is fine.

S3: OK

Tutor modeling

Tutor: One way of doing that would be to ... and this isn't to introduce a new direction... but now that you've done this is to walk back through it and make sure that it adds up. It was helpful to know, as you pointed out, that the subject is membrane potentials. But it's still, you know good to do it. So given the hypotheses that you have here, which ones can you literally, you know, are probably not going to be that relevant and which ones are more a priority? Remember for a kind of count at this point it's kind of good to think, "OK, if I was doing my little final exam on this one, how would I link my hypothesis and the problem? What physiologic mechanisms would let me link that?" So for example, say, you know, the toxin did it. And I happen to know that alpha-bungarotoxin blocks ACH receptors and if you block ACH receptors a person gets weak and so probably a Formosan krait crawled into her bed at night and bit her. Was she in Formosa?

Tutor verification/asking question

Tutor: Everybody clear on the grading system of strength?

S1: No.

Tutor: MD, you said yes?

S2: Well, when the physiotherapist came in she would do things like pull at your arms and see if you could pull back. And I think that if you're full strength, do you get a five if you're full? So 1, maybe you could move. So a 3/5 is... she's lost about 50% of her function.

Tutor: It's actually... you can think of these scales as logarithmic. 0 means no movement at all. You can't see anything. The person's completely floppy. 1 means that maybe, when they're like this you might see a little movement, but not against gravity. But if you ask them to lift their finger they can do it. And a 2 would be that you can move against gravity, but you really can't lift you whole arm. So with a three, you can lift the arm, but as soon as you put anything in it, you can't lift it. You're not holding your head up very well at all. And a 4 is kind of in between. A 5 is basically all the way down to the weakest person you could imagine could stand up and walk. So when you can't walk, you're probably a 4. So it's logarithmic rather than linear.

S3: But everybody gets 5 as long as they're walking.

Tutor: No matter how strong you are you don't get. Sometimes people will jokingly put down "5+!" when someone is really buffed up.

S3: Huh, huh, huh. (others laugh)

Tutor: Let me make sure that I got this right. So what you're saying so far is that if the unilateral geniculate and these six sub-nuclei or its distribution or is a map of different areas that there area different areas for magno and parvo cellular and different areas for the different fields?

S1: Hemi fields.

Tutor: Hemifields.

S1: Yes.

Tutor: So that if I said that you were seeing something moving in the right hemifield I would theoretically think that a certain nucleus...

S2: What's a right hemifield?

S3: It's that red area right up there... the visual field.

S2: So what you're saying is that this right hemifield...{not audible}. So Alan what was the question -- if we saw something moving in the right hemifield...

Tutor: and you wanted to do a PET scan of the nuclear activity in the brain...

S2: you might want to do that

S3: It would light up the whole thing, wouldn't it?

Tutor: it would?

Tutor: OK, so the way you've drawn the pump, it pumps out 2 Na and pumps out 2 K.

S1: 3. 3Na.

Tutor: so 3 Na go out and 2 K go in. That creates a current.

S2: An outward current. So actually, cells that have these ... it actually hyperpolarizes the membrane because you lose on charge out, one positive charge out.

S3: Got me wondering why no animals ever developed a just plain Na pump or a 4:1 pump. Do you know what I mean? Why 3:2? Such a small gain for one ATP.

S4: Well, you don't want to be too polarized, otherwise you'd be hyperpolarized and your nerves wouldn't work.

S2: See, how lucky it is for me that I don't even think those sorts of things. (laughs)

Tutor: So just from that, if you really did turn off the pump, you would immediately expect to get a change in membrane potential.

S3: Actually it would take a little time to run down because there's a huge--

Tutor: there's a part that wouldn't take anytime to run down at all and that's the current. Stop the pump, you turn off the current. That part of the hyperpolarization stops immediately.

S3: The current.

S2: The current through the...

S3: But I thought the voltage sep-- the potential difference would still exist, wouldn't it? For a while, until there was net movement of ions?

Tutor: How long?

S3: How long? Well, I'm just basing it on learning last semester that you can have a thousand action potentials without needing to run the pump to restock everything. So that made me think you had a fair amount of time. But I don't know how long a thousand action potentials take.
summarizing

S5: Do you guys want to go through this. right now we are on schedule that my time is up. Do you want to go through the exercise of what would happen if you turn off the pump.

S2: you'd die.

S5: Right, you'd die, but do you want to through the.. this...

S1: I don't...

S2: I think maybe...

S3: Or maybe we could crystallize the question. The question is: if there were no electric gradient, if there were just a chemical gradient, C's saying, everything would equalize. But then M brought up the question of: but does the fact that you have a voltage separation mean that you would still have, um, a potential difference on the two sides of the membrane.

LI clarification

S1: Did I miss one? No, OK. so we've got pyramidal cells in here. OK, here are little pyramidal cells. And what else do we want to put in, our stellate cells?

S2: 4.

S3: Simple.

S2: pyramidal are simple and complex.

S1: And then... so we have orientation columns that go down like this... that respond to different orientations.

S3: It says that each column contains a complete set of orientation columns, so that's what I don't understand. If this is a column and each one is supposed to...

S1: Oh, no, each hypercolumn.

S3: Oh and this is a hypercolumn? Oh...

S1: And a hypercolumn is column that responds to a particular visual image, is that right?

S4: Not to a visual image, but I think to a portion of the retina.

S3: I think it's enough columns so that all of the 360° are...

S1: OK.

S4: It says, "Each hypercolumn analyses a discrete region of the visual field."

S1: That makes sense.

S4: So which has got to correspond to a portion of the retina.

S3: OK.

S2: That's really interesting.

S1: OK, and so in that we have to have all the orientations represented. And then we also have to have represented from the ipsilateral eye and the contralateral eye.

S3: God, I get it!

S1: Right?

S3: Uh-huh.

LI generation

S1: OK, so what other learning issues do we want talk about?

S2: Cortical processing, sub-cortical processing, why do her drawings look like that, why does she speak--

S1: Right, right, right. How about stereognosis?

S3: We know what stereognosis means.

S1: Right but what area is related to having astereognosis.

S3: Why would she have astereognosis?

S1: Right. And this--

S2: What about the headache?

S1: --drawing, what is involved in...

S4: Let's call it left-sided neglect.

S1; OK, good, left-sided neglect.

S3: So what is and why do you have left-sided neglect.

Hypothesis clarification

S1: Well, I'll try my one that I said before which is that she took this medication, it's affecting her Na/K balance. The nerves that supply skeletal muscle use Na and K to somehow regulate the storage of ACH. And therefore, somehow having those things down regulated means that she is somehow unable to store enough of that neurotransmitter to successfully move her muscles. And that --

S2: Because of ACH release.

S1: Well, because she, I don't know. Because somehow she doesn't have enough of the neurotransmitter which she doesn't have enough of because of the cation. The rest of her body doesn't use cations to affect neurotransmitter storage or release and therefore it isn't affected.

S3: Except Ca affects the release of -- I think for sure -- of neurotransmitter.

S2: But he's talking about storage so it would be different. And I'm thinking that it has something to do with neural conduction. You know, at the motor neuron...specifically at the skeletal motor neurons. Like for some reason action potentials either aren't being generated or are being lost in the process and therefore she is unable to have motor movement. And I guess that involves the Na and K, you know, like levels, but for some reason the motor neurons are especially sensitive whereas the other ones are not? I don't know.

S4: Maybe the threshold is different.

S1: that's a good one.

S5: So S1 is the reason that you brought ACH into it is because that's one thing that distinguishes between skeletal and non-skeletal?

S1: No, I don't know. But Alan's used it so I used it. No, I don't know yet. I mean that's one of the things that we should find out.

S2: Well, ACH is the neurotransmitter at the NM junction.

S5: But I'm just asking is there a reason to think that it is at the neurotransmitter level as opposed to the resting membrane hyperpolarization level or maybe both, I mean... I was wondering why he decided on the ACH ... to bring in the neurotransmitter. It wasn't self-evident to me.

S1: Oh, well the reason I did that is because like I thought about trying the one that M proposed, but I couldn't think of a reason why motor neurons would be affected while sensory neurons weren't. So I thought, well, why don't we see if it's affecting... since we do know there is a difference between motor neurons and sensory neurons with respect to which neurotransmitter they use, maybe that's the connection.

S5: OK.

S1: It doesn't seem likely to me.

<u>Hypothesis generation</u>

S1: Sounds like she's on drugs.

S2: I know.

S3: That's one thing--

S4: Maybe she's having a retinal detachment.

S1: Huh! Yes!

S3: I think that it's probably a higher center thing.

S2: Yes!

S3: And I think that I could be, maybe --

S5: What edge?--

S3: maybe the occipital cortex or a tumor in the occipital cortex.

S4: Let's write down this--

<u>Defining/clarifying problem</u>

S1: Well, we shouldn't assume that this is complete information right? I mean just because they give us one nugget, we shouldn't feel obliged to explain the whole problem based on it.

S2: Um, is there a point to writing these questions? I mean will we be getting answers to these eventually? Or is this just practice...

S3: I think that it's good to ask questions.

S2: This is directed partially at you, Alan. Is there a way to get this feedback at all, are we...?

Tutor: Yeah, no no. The cases are all... I mean they're all designed so that they have different parts. Sometimes for example ... the case didn't. I mean the case didn't write in that she was 30 and that's reasonable information to know.

S2: Right.

Tutor: She's 30, she didn't eat anything special. She's not having trouble speaking. And she uses the medication for the five days before her period.

S3: Ooh. Every period.

S4: Is this--

S2: And for how many years has she been--

S1: Oh is she having her period now?

S4: yeah that's ... is she on the medication right now?

Tutor: Yeah, she just finished her period.

S5: She just finished it.

S1: She just took the medication.

S3: Five days before the start of her period.

S1: She took the medication, like, eight days ago?

S2: For the last seven years...

Tutor: She's just finished. She starts 5 days before her period and takes it during her period. Between five and eight days, depending on how much she's cramping and swelling.

S2: For how many years?

Tutor: I don't know. The last couple years.

S6: Well, maybe it's a combination.

S3: Well, yeah. So no I think that we need another variable.

S1: So I guess if it had to do with the optic radiation a lesion, then that affected the parietal area would include the optic radiation?

S2: Yeah. the optic radiations go from right behind the chiasm to almost back to the occipital lobe.

S1: So she could have some sort of lesion in the radiation and the parietal lobe? Is that possible?

S2: I mean she could have a lesion...right, exactly, good. Like something that's here in the parietal lobe that affecting optic radiation from the right eye, the right optic tract.

S3: So why's she getting headaches if there is no lesion there and there's no sensory in the brain itself?

Tutor: How do you get headaches?

S1: Didn't we hear today that they come from swelling and a certain amount of an inflammatory response so that if she has some sort of lesion or tumor or growth she might be having some sort of inflammation? or it might be pushing on other parts of the brain?

S4: You get feeling from the dura mater.

S3: The dura mater right? So that could be an aneurysm?

S1: Oh yeah, she might have an aneurysm.

<u>Planning session</u>

S1: Should we maybe read this and... figure out...?

Tutor: Yeah, you should probably...

S2: Do you want to facilitate?

S1: OK. Um... We end at 5? So we have 50 minutes. If we leave on time which we should (laughs). And... so... do we want to have a check out at the end?

group: OK

S1:... and then we can do learning issues. We'll just see how things go. At quarter of we'll definitely.. definitely, probably, maybe break and divide up learning issues. So... someone want to read this?

S1: S2. you're facilitating?

S2: Yes.

S1: Fantastico!

S2: Does anybody want to write the learning issues on the board or do we have them, um . . .

S3: They should be on there.

S4: It's these over here... the learning issues deferred.

group: uh-oh.

S6: I'll write them.

S2: And we have until 4 for this. How much time do we want for splitting up learning issues?

S1: Oh, that's right.

S4: We should take into account that we don't just divide up learning issues, we end up re-forming learning issues.

S2: Is fifteen minutes enough? Is that pushing it?

S5: I'll alert us at 3:45.

S1: OK, I really want to get back to these things because we always seem to lose ten minutes...

S2: Sorry.

S3: Mammals, it's mammals ... we can talk about mammals.

S4: OK, so {laughing}

S1: We talked about one and two, are we going to abandon this and go to cortical mapping in area 17.

S4: Well, to me one is... we have not done cortical processing. We have done subcortical processing.

S1: Right.